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SYMPOSIUM ON THE EARTH: ITS FIGURE, DIMENSIONS AND THE CONSTITUTION OF ITS INTERIOR.

(*Concluded from page 308.*)

IV.

VARIATIONS OF LATITUDE: THEIR BEARING UPON OUR KNOWLEDGE OF THE INTERIOR OF THE EARTH.

BY FRANK SCHLESINGER.

To review even hastily the contributions that astronomy has made to our knowledge of the figure and dimensions of the earth and the constitution of its interior, would consume more time than I can fairly claim as my share this afternoon. Let me therefore pass over those points that are on accepted ground and are matters of general agreement from the different points of view represented in this symposium; and let me dwell instead upon certain recent developments especially in need of consideration, concerning which the astronomer desires the criticism and help of the geologist, the seismologist, the physicist, and the meteorologist. These developments have come to us directly or indirectly through a study of latitude variations, so that most of what I shall have to say will deal with this subject.

Although variations of latitude are in a sense a very recent addi-

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tion to our knowledge, yet on the theoretical side, at least, we find the beginning more than a century and a half ago. In 1755 Euler considered "the rotation of solid and rigid bodies" in a memoir that is now recognized as the foundation stone for our edifice. He showed that if such a body is projected into space it will exhibit two kinds of rotation; the first of these is the familiar one that corresponds to the day in the case of the earth; the other is more subtle and corresponds to the variation of latitude. By reason of this the axis of the diurnal rotation is continually changing within the body, progressing in a regular way and coming back after a time to its earlier positions. An ordinary top gives us a simple example of this kind of rotation. The spinner imparts to the top a motion of translation as well as a rotation, and if we wish to study the rotation we must arrest the translation in some way. This we can do by letting the top fall upon a hard surface in which the iron peg soon wears a minute hole for itself, and the effect is to stop the translation of the top without modifying seriously the rotation. Then we can see that while the top is turning very rapidly around an axis, this axis is itself rotating in a comparatively leisurely way. Just the same thing is occurring with the earth: the point (or pole) at which the axis of the daily rotation pierces the surface of the earth is continually in motion. If we could take to the neighborhood of the pole a modern instrument, and if we could observe there at leisure and in comfort, we should have no particular difficulty in finding the position of the pole within a meter. But if we should repeat these observations a few months later we should find that the pole had wandered away to some distance. To be sure, this distance would not be great and all the wanderings of the pole that have thus far been observed could be plotted to true scale on the floor of a room not much larger than the one we are in. Of course if the pole is moving, so too is the earth's equator; and thus the latitudes of all points on the earth are varying. Such wanderings as these need not disturb the peace of mind of those gentlemen who like to discover the arctic or the antarctic pole. Under the circumstances that the polar explorer must work and with the meager instruments he can transport, he is glad to determine his latitude within half a mile of the truth.

We must understand that it is only in our time and only after the lapse of many years since Euler published his memoir, that latitude variations have actually been observed. There was nothing in Euler's theory to indicate how large a variation to look for, since this is a matter that depends upon the whole complex of "initial conditions," of which our knowledge is the very vaguest. But this theory does tell us what the period of the variation should be, since this depends upon the shape of the earth and the distribution of the material within it, and precisely the information that is here needed is afforded by a study of precession. Applying this information Euler was able to say that the period of the latitude variation should be ten months. Bessel at Königsberg in 1842, later Peters at Pulkova, Nyren also at Pulkova, Downing at Greenwich, and Newcomb at Washington, all searched their observations for evidence of a latitude variation having a period of ten months, but all in vain. Astronomers concluded that if latitude variations existed at all, their extent was too small to be detected by instruments of the precision that had then been attained.

Toward the end of the nineteenth century vague whisperings that this conclusion might be incorrect seem to have been in the air. But the first clear word to this effect came in 1888 from the lips of Küstner at Berlin. He had invented and applied a method for determining the amount of the aberration of light; but he found that his observations gave well-nigh impossible results, agreeing neither among themselves nor with earlier reliable observations. By a nice chain of logic he was able to exclude one possible explanation after another until there was left only the supposition that the latitude of his station had changed while his observations were in progress. Next he examined nearly contemporaneous observations made at other places, and when he found that he could account for certain puzzling discrepancies, he no longer hesitated to announce that latitudes were variable after all.

This announcement awoke the liveliest interest and encountered no little scepticism. Special observations were at once set on foot at various observatories in Europe and America, as well as at a station near Honolulu in the Sandwich Islands. These islands are

about opposite in longitude to the European stations, and this was the reason for establishing a station there. For obviously if the pole is really changing its place then the changes in latitude for two opposite stations will be the reverse of each other. When in 1893 this was found actually to be the case, other possible explanations for the observed phenomena at once fell down, and latitude variations became for the first time a universally accepted fact.

Much time and effort have since been expended in attempting to formulate the "laws" of latitude variations and to give them a mechanical interpretation. But observation has shown that the variations are of unexpected complicity, and as a consequence we are still very far from having satisfactory knowledge of this subject. By the same token it is probable that an intensive study of these variations, particularly from points of view other than the astronomical, will teach us much concerning the interior of the earth as well as some of its surface phenomena.

It was the late Dr. Chandler, of Cambridge, Massachusetts, who took the lead in investigating the nature of latitude variations. By overhauling ancient observations (made of course without any reference to the present subject) he was able to trace the presence of the variations back to the time of Bradley in the middle of the eighteenth century. Thus it happens that at the very time that Euler was writing the first theoretical paper on the subject, Bradley had already begun making the observations from which the actual existence of latitude variations might have been proven at once. Chandler was able to gather similar evidence from other miscellaneous series of observations and thus to set down a tolerably continuous record of the variations during a century and a half. However interesting a fact this may be from an historical point of view, it does not help very much in a practical study of the subject. There are two reasons for this: first, it is only for European stations (and for the most part only for Greenwich) that we have any knowledge of these earlier variations; the other component of the wanderings of the pole, namely that in the meridian at right angles to the meridian of Greenwich, did not begin to be known until very recently. Again, these ancient observations were undertaken for

certain definite purposes that they served as well as could be expected for their time; but they were not intended and are not well suited for precise determinations of the latitude. Close acquaintance with the subject has taught us that exceedingly delicate observations are necessary to define the variations with adequate accuracy. If I held in my hands two plumb lines half a meter apart, they would not be quite parallel to each other, though both are exactly vertical; if they were prolonged, they would meet somewhere near the center of the earth, 4,000 miles below. The angle between them is a little less than 0".02 and represents approximately the accuracy that is demanded and that has recently been attained in latitude observations. This success is due chiefly to the International Geodetic Association which has organized an "international latitude service" of high efficiency, and to whose efforts and experience are due the improvements in instruments and methods that have made possible this extraordinary degree of precision. Since 1899, the Association has maintained six observing stations for this sole purpose, two of these being in our own country. One of the minor effects of the war that is now raging in Europe will be the discontinuance of some of these stations. One of the American stations has already been abandoned and the same fate will overtake the other in June, 1916, unless some independent means of maintaining it, at least temporarily, presents itself soon. An interruption of these observations would be a great pity, for this is one of the cases where a continuous record is highly desirable.

To return to Chandler and his work on these variations, perhaps the most important of his achievements was to show that the principal term in the variations, instead of having a period of ten months in accordance with Euler's theory, has in reality a period of fourteen months. This difference explains the failure of Bessel and all the others who preceded Küstner to find a latitude variation in their observations; for, relying upon Euler's results, they had all tested their observations for the ten-month variation and had sought for no other variation. For the same reason, Chandler's announcement of the longer period was received with incredulity in some quarters, and this feeling did not vanish until Newcomb

pointed out that Euler had made a certain assumption regarding the interior of the earth that had in the meantime been universally discarded; his period of ten months applies in fact only to a perfectly rigid and unyielding earth. Newcomb showed that if the earth yields to deformation to the same extent as though it were composed throughout of steel, then Euler's period would be lengthened to about fourteen months. Here we have the first dependable determination of the rigidity of the earth, a result that has since been confirmed in several ways, particularly by a measurement of "bodily tides" in the earth.

The fourteen-month term (or the modified Eulerian term as it is now called) has been under accurate observation for a quarter of a century. The period can probably (though not certainly) be regarded as constant. This is what we should expect, for a change in this period would call for a sensible alteration in the distribution of the material within the earth, or a change in the rigidity of the earth. The amplitude of this term presents a very puzzling problem. Its usual value is about 0″.27, but twice in recent years it has jumped to about 0″.40. Such a change could be accounted for by supposing that the earth had received a severe blow or a succession of milder blows tending in the same direction. We are reminded that both Milne and Helmert have suggested that there might be a direct connection between latitude variations and earthquakes. This suggestion was originally made by Milne very early in this century when the astronomical data necessary to test it were still very meager. It is to be hoped that the question will be taken up again in the light of the information that has been added during the past ten or twelve years.

Though the Eulerian term is the largest part of the latitude variation, it is by no means the only important one. We have next an annual term with a maximum amplitude of about 0″.20. We may say with some confidence that this term is seasonal and meteorological in its origin, but at present no more definite statement would be warranted. It was early suggested that ocean currents might cause this variation. These currents would have to vary greatly with the season, either in the volume or the speed of the flow, or in

its direction; for an unvarying current would merely modify the Eulerian term once for all and would leave the latitude variations otherwise unchanged. A similar suggestion has been made with regard to air currents, and appeal has also been made to unequal deposits of snow and ice on two opposite hemispheres of the earth, to account for the annual term. It seems to me that these explanations have not been subjected to the critical numerical tests that are possible and desirable. The meteorological data are doubtless competent to enable us to compute at least the order of the effects in the latitude variations that we should expect from these various causes. Furthermore the annual term is probably variable in its amplitude, and it is important to ascertain how (if at all) these changes are related to the corresponding meteorological observations.

One other term must be mentioned in this brief summary. A few years ago Kimura of Japan made the important discovery (the most striking contribution to astronomy that has ever come out of Asia) that the latitudes of all stations are affected by a variation that does not depend upon the longitude but which is the same for all points in the same latitude. In other words there is present a variation that is not due to the wanderings of the pole. To ascertain more closely the nature of this term, the International Geodetic Association extended its latitude service temporarily to the southern hemisphere, with the result that the term was found to be of precisely the kind that would be caused by an annual wandering of the center of gravity of the earth to and fro along the axis of rotation. This must be regarded merely as an illustration and not as an explanation, for so great a change (about three meters) in the position of the center of gravity is excluded on other and very conclusive grounds. No plausible explanation for the Kimura term has as yet made its appearance, and as a consequence the reality of the term has been questioned from every possible point of view. Many explanations have been advanced, each of which sought to account for the term as merely an instrumental effect or the like, just as was the case twenty years earlier with the whole of the latitude variation itself. Against such attempts the Kimura term has

held up very well. It is not too much to say that at the present time all but one of the numerous explanations of this class have been disposed of; this exception deserves a brief mention, particularly as it calls loudly for the attention of the meteorologist. Let us suppose that the layers of equal density in the atmosphere above a station are not horizontal, but that they are sensibly inclined. If this occurs without our knowledge, as it would under ordinary circumstances, then we should apply refraction to our observations in a slightly erroneous way and we should derive a value for the latitude that is not quite correct. Let us suppose further that this effect were a world-wide one and that in any given month there would be a pronounced tendency for the inclination to be in the same sense in all latitudes, north and south, as well as in all longitudes. Then we should have a set of circumstances that would account for the Kimura term as an atmospheric effect, and therefore it would be excluded as a real variation of latitude. So far as the astronomer is able to testify, the evidence is against the occurrence of such tilts in the atmosphere. The inclination required to account quantitatively for the amplitude of the Kimura term is over two minutes of arc, or a slope of about one part in fifteen hundred. Presumably in a few years we shall be able to say something more definite as to the possibility of the existence of such conditions. My own opinion is that this explanation, like so many others of similar character that have been suggested for the Kimura term, will be found untenable. Further I venture to think that latitude variations as a whole will find their explanations less on the surface of the earth and more in its interior than seems now to be the generally accepted opinion.

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A PRACTICAL RATIONAL ALPHABET.

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(*Read October 1, 1915.*)

How to reform English orthography, and reduce it to simple regularity is an interesting problem. Repeated efforts have been persistently made in that direction. Among others, overhasty enthusiasts, in their disgust at the irregularities and phonetic inadequacies of the established English spelling, have insisted that a comparatively few of the most glaring irregularities should be "simplified" at once, hoping that later on another larger batch of "corrections" may be adopted. Of course, such alterations from the established usage can only come gradually into general, or established, use; not in less than fifty or seventy years, as may be seen in the few small changes urged by Noah Webster. Meanwhile, if the alterations meet with somewhat wide acceptance, there must be, on the whole, very greatly increased irregularity in English spelling, approaching, indeed, chaotic lawlessness. The repetition, and thereby prolongation of this painful unruly condition of our orthography in such an ill-considered effort at reform must remind one of the pretended humanity of cutting off a dog's tail by stages of an inch at a time. Would it not be far better to devise a practical and thoroughgoing system of orthography to be used alongside of the present established usage; and to become more and more used, until at last, it may become altogether adopted and universally used?

There are serious difficulties, however, in setting up a practical and thoroughgoing system of orthography. Any plan of reformed orthography should never fail to keep in mind the necessity of being thoroughly practical, if the least hope be entertained of its coming into universal, or even common, use. The great, widespread vogue of the Roman alphabet is doubtless due to its even rude simplicity; and in many hundred years it has been impossible to introduce into general use more than a very few extremely simple modifications of

the original forms of the letters: as for instance the carvilium to distinguish G from C and the distinction between J and I and between U and V, which appear to be still struggling for complete prevalence. It may, however, be borne in mind that notable additions to the Arabic alphabet have been made and accepted in order to express additional sounds in Persian or other languages: but it is noticeable that such added forms are strictly in keeping with the original character of the alphabet. The Russians have also strongly modified the Roman alphabet, and not always quite in keeping with the rude simplicity of its general character; yet have established its use throughout a great empire. In proposing new forms of letters for newly distinguished sounds, it is certainly advisable to maintain some restraint upon one's fancy, to adhere to the utmost simplicity, and to depart as little as possible from the general character of bare simplicity of the Roman alphabet, making use, so far as possible, of old devices, and putting forward as few novelties as possible, to be learned and made familiar. It seems highly desirable to avoid the use of altogether outlandish forms like the fully obsolete old Anglo-Saxon letters, wholly out of keeping with our modern alphabet; or to offend the eye by intermixing italic letters with Roman and by other tasteless similar devices, or by interspersing inverted letters, though to be sure of good Roman shape. Above all, however, let us avoid separate diacritical marks to distinguish sounds, marks that are a nuisance to write, an obscurity to read, and by their occasional forgetful omission a fruitful source of misleading. Especially the use of diacritical marks in a way opposed to their time-honored significance, is to be reprehended; as for example, the use of an accent to indicate merely the length of a vowel. Such practice has misled commonly into various errors of pronunciation of some oriental words. We shall see if there be any serious difficulty in getting handsomely along without any of those hastily, inconsiderately adopted, tempting, shallow, easy, but terrible, makeshifts. There are some restraints, or guides, which must cogently influence our choice of letters or symbols to be used in indicating the different sounds of the language. It is highly desirable, or absolutely necessary, that each sound should be indicated by only one letter, and that each letter should have but one sound; and it would

be absurd to acknowledge that principle, and then as in Volapuek and Esperanto, at the very outset give to *z* the sound of two letters, *ts*, merely because it happens to have those sounds in German. Another important principle is to give to letters or devices the force that they already have, and long have had, in the languages where they have been in use. In general, the customary practice of the majority should have sway, requiring the minimum of new learning. As English is far and away the most numerously spoken language throughout the world, the sounds to be attributed to the consonant letters should be as in English; though, owing to the extreme irregularity and variety of the English vowel letters, they must give place to letters that are more prevalent in the other European languages. The English consonant *y*, for example, should be used; not, as in Esperanto, the letter *j*, which has that sound among the comparatively small number who use German and Italian. In Volapuek, *j* is made to serve for the English *sh*, a most unheard-of use.

In English, the combinations *ch*, *sh*, *th* and *wh* each is used for a single sound, and it is desirable to substitute for it a single letter. Would it not be highly practical to write those sounds by means, in each case, of merely the first of the two letters with a subscript small appendage somewhat similar to the old device of the French cedilla, though a little different in form, to represent the letter *h*, and having a more or less distant resemblance to it in shape? In cursive writing, the resemblance to an *h* need not by any means be close, and may be really abbreviated, as there would be no danger of misunderstanding. We have, thereby, four new characters with but a single device to remember, and that not a new one, and the new forms are entirely in keeping with our old alphabet and with already customary methods. As to the sound of *ch* in *church*, it is sometimes maintained that it is in reality a sound compounded of *t* followed by *sh*. But that is clearly an error; for even the ear can distinguish a difference in the sounds, and the sound of *ch* is as distinctly different as is the sound of the opening or closing of a somewhat tightly swollen door, compared to the mild clapping to of a well-fitting closure. The peculiarity of the contact of the tongue and roof of the mouth, with the consequent vibrations of the roof of the mouth, occasions a peculiar sound different from *t* and from

sh. A corresponding difference occurs between the sound of a smack with the lips and *p* or *b*. The sound of *zh*, as in pleasure, would, of course, be indicated by *z* with a subscript *h*. If it be desired (unlike ordinary English) to distinguish the sound of *th* in *this* from that in *thin*, the logically analogous and simple mode of writing it would be with a *d* with a subscript *h*. The whispered, or surd, *y*, heard in the word *hue*, might also be indicated by a *y* with a subscript *h*. The guttural sounds indicated in oriental transliteration by *kh* and *gh*, would likewise be represented by *k* or *g* with a subscript *h*. Until types of these new forms are to be had, we may provisionally, instead of the subscript *h*, use a small *h* at the side: c_h, s_h, t_h, d_h, k_h, g_h, w_h, y_h. The simple sound written in English with *ng* should be indicated (as proposed so long ago as Benjamin Franklin) by a character similar to a *g* but with the upper part in the form of an *n*, for which there is already type.

Other consonant sounds, the so-called cerebral sounds, occurring, for example, in the Sanscrit and in the dialect of Peking, could be simply indicated in a similar manner, by giving to the upper part of the corresponding letter the shape of an *r*; since those sounds are made with the tongue rolled up, as for an *r*. In Sanscrit, such a modification of *sh* occurs and in the Peking dialect *y* is so pronounced, with the tongue rolled up, and may be indicated by a *y* with the upper right hand fork in the shape of an *r* (provisionally $s_{\cup}^{r}$, and y^{r}).

With these four or five simple characters, we have then a full supply of consonants without going outside of the ordinary English usage; *b, c, ch, d, dh, f, g* (always as in *give, get*), *j, k, l, m, n, p, r, s, sh, t, th, v, w, y, z, zh;* omitting *q*, and *x*, as superfluous; and using *c*, only with the subscript *h*. Indeed as the *c* is only so used, even if the subscript *h* should be omitted there would be no danger of confusion, and *c* would have before all vowels the same sound that it has in Italian before *e*, and *i*. *H* is sometimes reckoned as a consonant, but, of course, erroneously, as it is the whispered form of the vowel that follows it.

As already intimated, order out of the chaos of English vowels is only to be attained by adopting the more uniform practice of the European continental countries, with *a*, as in *arm*, *o* as in *note*, *u* as

in *rule, i* as in *pique, e* as in *they;* and, for the vowels, we must abandon the hope of indicating by a separate character every one of the infinite number of shades of sound, a few of which occur in such series of vowels as in: *hate, hale, hare, hairy, Harry, hal, hat.* The progress of enlightenment in thousands of years has led to far greater nicety of distinction in vowel sounds than was common formerly. But instead of five or six vowels that it was then found worth while to indicate by separate characters, it would now be hardly practical to have distinct letters for more than eighteen or twenty vowels and that number may be very practically arranged.

A difficulty in bringing into general use any such somewhat nicely adjusted system of indicating the sounds, especially the vowel sounds, of any language is that the pronunciation of words is different in different regions and even among different families and individuals of the same region; nay, even with the same individual according to varying emphasis in different connections, as *to* in "going to Boston," and "to and fro" and the pronunciation sometimes varies through slackness or slovenliness of articulation or enunciation, as in substituting a slight vowel sound for the consonants *y* and *w* in such words as *they* and *snow,* or in dropping *r* altogether after a vowel and before a consonant, as in *arm.* Hence strict regard to phonetics would give the same word several different forms according to the taste or habits of different writers, and stand seriously in the way of the uniformity of spelling that would be extremely desirable for at least a literary language to be used in common by a numerous people.

As regards the vowels Professor Samuel Porter over forty-eight years ago, in the *American Journal of Science,* September, 1866, excellently classified the readily distinguishable vowel sounds of English and other principal European languages, and arranged them according to their physiological mode of formation, with a simple illustration indicating nine different parts of the mouth where the tongue is placed to give the form of cavity, which with the issuing breath, will produce each vowel sound. So simple are the plan and the illustration that they have been perfectly successful in inducing very ignorant Orientals (in India and China) to indicate thoroughly and simply the mode of formation of some of their most

peculiar sounds, which to ordinary foreigners without Porter's help, and with merely the ear as a guide, are mysterious and even considered quite unattainable. He distinguishes nine points at which the tongue is placed, and at each of those points, four degrees of openness; making thereby thirty-six readily distinguishable vowels. But a number of them are not in ordinary use, and are therefore not to be considered in any orthographic scheme. A few additions are to be made on account of the effect of stiffening the lips, changing the sound. In order to accommodate ourselves to this classification of the vowels it is desirable to add to our letters æ (not a new combination) as ae in German *Maedchen,* for the sound of *a* in *care;* and oe (again not new), nearly like the oe in German *schoen* for certain closely allied sounds; and a new character, like the Swedish *a,* with an *o* over it; but contracted into a single form, for the sounds, like *a* in *war,* or *o* in *lord,* or *oa* in *broad.* Yet another new form may be added, *e* with a stroke like an accent just to its left, to correspond with the French acute-accented *é.* We have, then, nine characters for Porter's nine groups of four vowels each. He calls attention to the fact that in each group of four vowels, differing only in the degree of closeness of the tongue at the same place in the mouth, two of the four are long and two short. Let us therefore represent the long vowels by the ancient device of simply doubling (with slight contraction) the letter used for the short vowels, as the Greeks already set us the example with their omega. All the vowels can in like manner be doubled, and somewhat contracted, making at once eighteen easily written and easily read vowels conforming well to the already established character of our alphabet. Until appropriate type for the purpose are to be had, we might provisionally merely double the present letters; as: aa, ee, etc. In one or two cases the number can be increased by indicating a labial modification of the vowel by means of a small upright stroke, an abbreviated *l* (provisionally a small *l*), close to the right hand of the letter. In this way, we are easily provided with about twenty vowels, apparently an ample supply for the English language.

Let us now consider the vowels one by one, more particularly. In group I, the *a* of *last, ask, chant,* is short; while that of *father*

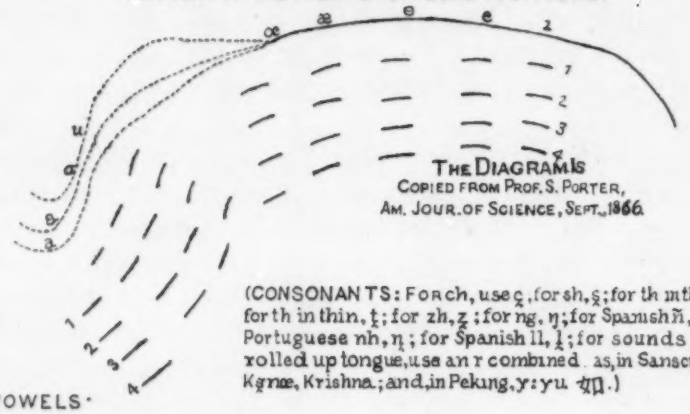
and *calm* is long; and that of *baa, ah, arm, charge* is still broader. The two last would therefore be written with a double letter (provisionally aa); and there would be no need to distinguish in writing between these two, because there is distinction enough in the following *r* or *h*.

In group II, the two closer vowels, as (long) in *war, lord, awe, pause,* or (shorter) *all, water, long, daughter,* are both labially modified, by stiffening the lips; and can be so indicated by means of a small upright stroke (an abbreviated *l,* provisionally a small *l*) just to the right of the letter. The longer vowel can be indicated by doubling, as already described. The shorter and not labially modified vowel of the second degree of openness is heard in the words *salt, although, cross, horror;* and the third degree of openness, also not labially modified, occurs in *sod, nor, off, what, knowledge;* and may be written with an *a* combined with an *o,* like the corresponding Swedish letter, but more contracted. These two closely similar vowel sounds, scarcely distinguishable by ordinary ears, it seems hardly worth while to provide with separate letters (though the distinction of the third degree might be marked by a small 3 just to the right of the letter). The fourth degree of openness does not occur in ordinary speech.

In group III, in like manner, the least open vowel, as in *note, toe, low, loaf, door, mourn,* being longer, may be written with a double letter (like the Greek omega), or, provisionally, by a repetition of the single letter, *oo*; and might be marked as labially modified, in the way already indicated. But this is hardly necessary, because, in English, it always has that modification, making it unnecessary to mark it. The next degree of openness is likewise always labially modified, and being short would be written with a single letter. It is also distinguished by being an unaccented vowel. The third degree of openness, as in *not, dot, folly, knock, proper, bite, eye* (*oy,* a short *o* followed by the consonant *y*) occurs only in accented syllables, and is thereby sufficiently distinguished.

In group IV, the long sound of the vowel in *rule, sure, fool, pool, moon, shoe, soup,* would be written with a double vowel (provisionally by *uu*), while the vowel of the second degree of openness, as in *full, pull, bosom, woman, should, good, foot, book,* would be

DIAGRAM OF THE PALATO-LINGUAL POSITIONS.



THE DIAGRAMS
COPIED FROM PROF. S. PORTER,
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(CONSONANTS: For ch, use ç, for sh, ş; for th in this, ḍ; for th in thin, ţ; for zh, ʒ; for ng, ŋ; for Spanish ñ, and Portuguese nh, ɳ; for Spanish ll, ļ; for sounds with rolled up tongue, use an r combined as, in Sanscrit, ṛ: Kṛṣṇa, Krishna; and, in Pekung, y: yu 尤.)

VOWELS.

I A, Ⱥ, ɜ, ɑ, ɑ, Ⱥ, Ⱥ
1. as in last, ask, chant: last, ask, çant.
2. as in father, calm: father, kɑm.
3. as in baa, ah, arm, charge: bɑ, ɑ, ɑrm, çɑrj
4. (Not in good English.)

II. Ɐ, Ⱥ, ɑ, ɑ, ɐ, Ɐ, ɑ, ɑ.
1. as in awe, war, lord, pause: ɑ, wɑr, lɑrd, pɑz, (labially modified—lips stiff).
2. as in all, water, long, daughter: ɑl, wɑter, lɑng, dɑter, (labial)
2. as in salt, although, cross, horror: salt, aldo, kras, harɑr.
3. as in sod, nor, off, what, knowledge: sad, nar, af, what, nalej.
4. (Not in good English.)

III. O, Ꝍ, o, o, o, ꝍ, o, o.
1. as in note, toe, low, loaf, door, mourn, beau. nɷt, tɷ, lɷ, lɷf, dɷr, mɷrn, bɷ.
2. as in opinion, agony, propose, mellow: opinɷen, ægɷne, propɷz, melo (unaccented).
3. as in not, dot, folly, knock, proper, eye, bite: not, dot, fole, nok, propɷr, oy, boyt
4. (Not in good English.)

IV. U, Ʊ, u, u, u, u, u
1. as in rule, sure, fool, pool, moon, move, shoe: rul, şur, ful, pul, mun, muv, şu.
2. as in full, pull, bosom, woman, should, good: ful, pul, buzɷm, wumɷn, şud, gud.
3. as in fulfil, willful: fulfil, wilful—(unaccented).
4. (Not in good English.)

V. Œ, Œ, œ, œ, Œ, Œ, ɑ, ɑ.
1. (Not in English—the German œ, French eu.)
2. as in girl, virtue, mercy, myrtle, earl: gœrl, vœrtyu, mœrse, mœrtl, œrl—(before r).
3. as in up, but, cousin, rough, dove, done: œp, bœt, kœzin, rœf, dœv, dœn.
4. as in burr, church, work: bœr, çœrç, wœrk—(before r, accented).

VI. Æ, Æ, æ, æ, Æ, Æ, ɑ, ɑ.
1. as in their, fair, parent: ḍær, fær, pærent.
2. as in care, there, prayer, hair, pair: kær, ḍær, prær, hær, pær—(before r).
3. as in cat, man, sad, hap: kæt, mæn, sæd, hæp—(accented, no r).
4. (Not in good English.)

VII. E, E, e, e, E, E, e, e.
1. as in they, grey, vein, great, name, fate: dey, grey, veyn, greyt, neym, feyt.
2. as in nitrate, climate: noytret, kloymet—(unaccented).
3. as in get, egg, red, mend: get, eg, red, mend—(accented).
4. (Not in English.)

VIII Ɇ, e, Ɇ, e.
1. (Not in English—the French é.)
2. as in guinea, valley, carried, city: gine, vælɇ, kæred, citɇ—(unaccent'd).
3. as in goodness, college: gudnes, kalej—(unaccented).
4. (Not in English.)

IX. I, Ɪ, ı, ɨ, Ɪ, ɪ, ɨ
1. as in pique, machine, field, eat, eve, deep: pik, maşin, fild, it, iv, dip.
2. as in divine, vehicle, mandarin: divoyn, vihikl, mændarin—(unaccented).
3. as in pin, hit, sin, will: pin, hit, sin, will—(accented).
4. (Not in good English.)—(The French u would be ɨ.)

(Until proper type can be had, use double letters for long vowels.) B.S.L.

written with a single letter. Both these vowels are labially modified, and might be so marked, in the way already indicated, but it is unnecessary so to mark them, because there is no vowel in English with which they could be confounded. In the third degree of openness, the unaccented vowels in *fulfill,* and *willful,* occur; but (written with a single letter) are sufficiently distinguished by the absence of accent. The fourth degree of openness does not occur in good English.

In group V, the first and second degrees of openness, occur in the German oe, and the French eu (nearly, though not quite, the same); but not in English. The second degree of openness without labial modification occurs in English only before *r* as in *mercy, virtue, girl, myrtle, earl, pearl, earth;* and may be written with a single letter (œ). In the third degree of openness, likewise short, and to be written with a single letter, occurs the so-called natural vowel, accented, and without *r,* as in *up, but.* In the fourth degree (written with a double vowel), long, occurs before *r* the vowel sound of *burr, occur.*

In group VI, the long sound, with a double letter (provisionally, the single letter repeated, æ æ), is heard as the *a* in *parent, ei* in *their, ai* in *fair.* It is the German *ae* in *Maedchen,* and the French *è* in *après, scène, père.* The second degree of openness, with a single letter, is heard in *care, there, prayer, heir, pair;* in each case followed by the sound *r.* Without that sound of *r,* the third degree of openness gives us, with the same letter, the *a* in *at, cat, man, sad, hap.* The absence of the *r* makes it unnecessary for them to distinguish the two slightly different vowels.

In group VII, the first degree of openness with a double letter, or, provisionally, the single letter repeated, *ee,* gives us the *e* in *they, grey,* and the like sounds in *fate, name, great, vein, hail, pay;* the German *mehr, jeder, ledig, See.* The second degree of openness, with a single letter, gives us the *a* of unaccented syllables, as in *nitrate, climate.* The third degree of openness, with the same single letter, occurs in accented syllables, as in *get, egg, red, mend.* The fourth degree does not occur in English.

In group VIII, the first and fourth degree of openness do not occur in English. The first one, to be written with a double letter,

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occurs in the French acute-accented *é* and *ai*. The second degree of openness (written with a single letter, provisionally, ¹e, an *e* with a small upright mark, or figure 1, above at its left) occurs in English in unaccented syllables only, as in *guinea, valley, carried, city*. The third degree of openness (likewise a single letter) differs so slightly from the second as hardly to need a separate character, though it might be marked with a small abbreviated 3 put to the right and upper part of the letter *e*. It occurs in the unaccented syllables *goodness, college*.

In group IX, the first degree of openness, to be marked with a double letter (provisionally, *ii*), is found in the *i* of *pique, machine*. When this is labially modified by stiffening the lips, it becomes the French *u*, as in *ruse*, and the German *ue*, as in *ueber*, to be marked with a small stroke, an abbreviated *l*, at the right of the letter. The second degree of openness, to be marked by a single letter, occurs in unaccented syllables as in *divine, vehicle, mitigate*. The fourth degree of openness does not occur in English.

We have, then, for the vowels nineteen letters; distinguishing all the readily distinguishable vowels used in English. In two or three cases the distinction is indicated by the accent as in certain unaccented syllables, as in *fulfill, goodness;* and in other cases by the subsequence of the sound *r*, as in *girl*. Even these slight differences could be indicated by a scrupulous writer with an abbreviated figure *3* alongside, to the right, and at the upper corner, of the letter.

Having thus made possible the writing of English with unmistakable letters, each letter for a single sound, and each readily distinguished sound by a single letter, a strong reason is advanced in favor of the general adoption of English as a universal language. Indeed, it is ardently to be hoped that eventually some one language may become universal, and known to the whole human race. Latin was formerly so widely known and extensively used among the more civilized nations as to give some color to its claim to become the universal language. But the gradually increased refinement of ideas in modern times has apparently made it impossible to be satisfied with so bald and rude a method of communication. The numerous artificial languages proposed for this purpose, even if not

liable to the same objection, or to greater crudity, are yet additional languages to be learned. English already known to a much larger number of men than any other language, seems to be, by all odds, the best adapted to become, perhaps with slight modifications, a universal language. The simplicity of its grammar, aside from orthography, makes it remarkably easy for foreigners to learn; and, for use in universal form, the comparatively few irregularities of grammar might considerately be eliminated, so that (in universal form) it might be allowed to say mouses, instead of mice, and digged instead of dug. English has already shown its capacity to express perfectly the finest distinctions of ideas and must in that respect far excel any artificial language, like Esperanto, or Volapuek, with their rude, bald, lack, for example, of the definite or indefinite articles. A rational, phonetic, practical spelling would, then, make English ideally perfect for a universal language. Clearly, for that purpose, the usage of speakers of some region, or of some degree of cultivation, with some degree of emphasis, must be selected as the norm to which the written language should conform, in order to make the writing and spelling in the main, though not always in every minute detail, phonetic. Well taught children should, then, everywhere learn to pronounce the words as they are spelled, and not be allowed to drop the sound of *r* in arm, or pervert the sound of the English long *u* (like *yu*, except after the sound of *ch, j, r, sh, zh,* or *y*). Normal schools should train teachers in these details so that the children may be properly drilled. In that way the language would be rightly conserved, and would tend to become fit for universal use.

One serious difficulty in the adoption of any such improvements of our alphabet is that there are so many men who excel more in persuasive eloquence, in "the gift of the gab," than in a thorough knowledge of phonetics and inclination to careful reflection. Cadmus could not have been a ready tongued, shallow utterer of rapidly up-bubbling superficial thoughts. A group, or committee, or society of such quick-witted individuals (perhaps some of them so densely ignorant as to suppose *h* to be a consonant, instead of the whispered, or surd, form of its following vowel, or to insist that the English *ch,* and *j* are compounded of sounds distinguishable even by the ear, and as much unlike the real ones as the bursting open, or banging shut of a tightly swollen door, is to the mild clapping to or open-

ing of a well-fitting closure), may make bold to put forward by their majority vote some alphabetic, or orthographic, system (as the Japanese Roman Letter Society did), and may really delay for a long time the adoption of an altogether rational and practical method. It would be much better for individuals to propose their own plans, and put them into use by themselves and by a portion of the public. Gradually, the best of such plans would take the lead, and come into more and more general use, without having to overcome at the outset the prestige of the dominant approval of a high-sounding society or committee. In any case, it would clearly take many years for such a rational new system fully to supplant the present established usage.

Meantime, it might be advisable to do something towards simplifying the learning of the present established spelling. To be sure, the difficulty of learning it has been much exaggerated, owing to the general extreme neglect of the study. It seems, however, possible that the six weeks or so that appears to be ample for a half-grown boy or girl to learn to spell well might be reduced to a couple of weeks, at most, with a properly arranged booklet; so that the present multitudinous army of typists might readily fit themselves to avoid tormenting their employers by ignorance of so simple an art as spelling.

But however advantageous a simple, purely phonetic spelling might be to a defectively educated typist, or to an adult foreigner, let it not by any means be imagined that the time spent by children in acquiring our more complicated established orthography is uselessly thrown away. On the contrary, it is a highly useful discipline, not only training the memory in a simple way, well adapted to young children, but giving most valuable habits of close and accurate minute observation (the precision that is the most efficient aid to the conservation of language), and enabling the easy understanding and remembering of the proper mode of writing a new word or name. Such habits may also be acquired by certain games of children, but in a way not a whit more interesting or "useful" than the old-fashioned spelling match. The comparatively recent way of teaching to read by the general appearance of the word, and with total neglect of syllabical spelling, is detestable, and produces results that are full of torture and disgust to those who have to listen to such reading.

THE CAMBRIAN MANGANESE DEPOSITS OF CONCEPTION AND TRINITY BAYS, NEWFOUNDLAND.

By NELSON C. DALE.

(*Read April 25, 1914*)

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I. INTRODUCTION.

This paper is based upon data collected during the summers of 1912 and 1913. The former season, Mr. A. O. Hayes and Prof. van Ingen of Princeton University, while making a study of the general geology, stratigraphy, and palæontology of the shores of Conception Bay, Newfoundland, in connection with the investigation of the iron ores of Great Bell Island, came upon the manganiferous rocks of the Lower Cambrian exposed at Manuels, Topsail, Brigus, and other places. They were immediately struck by the unusual lithological and mineralogical characteristics and by the excellent state of preservation, particularly at Manuels, of what are undoubtedly primary

bedded deposits. Some collections and notes then taken of these interesting rocks were later placed at the disposal of the writer for further investigation. The following summer of 1913, the writer as a member of the Princeton Newfoundland Expedition undertook a more detailed study of these deposits at the various localities where the manganese had been found the preceding summer, and also of a deposit of the same age on the northern shore of Trinity Bay.

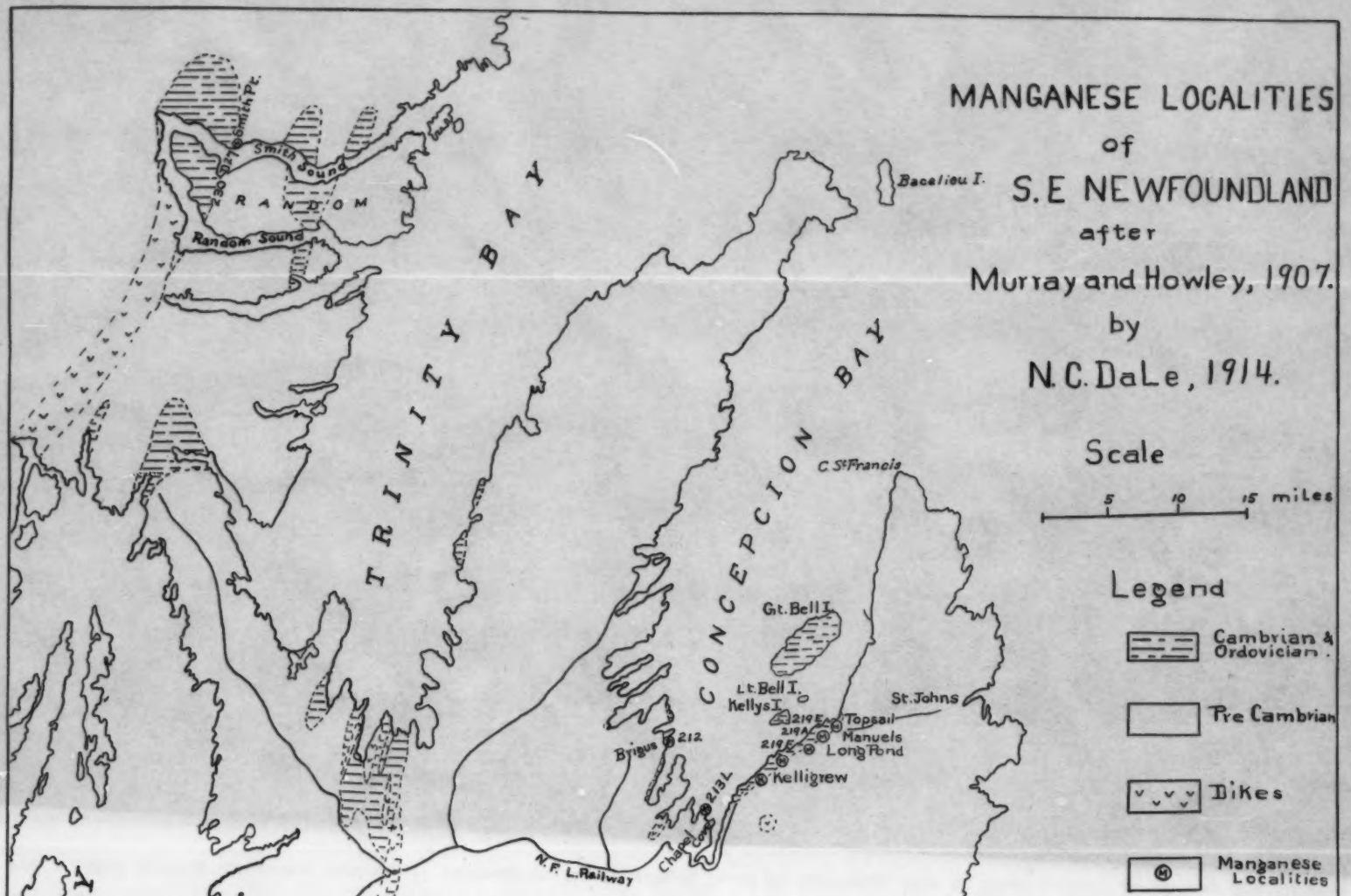
There are so few syngenetic manganese deposits which still retain their primary unaltered characters and are found to occur at the same horizon over such a wide area that a somewhat detailed investigation gave promise of yielding results of value. In this paper therefore there has been an attempt to present as comprehensive a study of the manganese of southeastern Newfoundland as our knowledge of this hitherto but little investigated region will allow.

The subject matter is primarily chemical in its nature and the analyses herewith presented are from samples taken from the principal manganese-bearing beds. Many more analyses however could have been made and in fact many more should be made if the deposits are to be seriously investigated for commercial purposes. The analyses of the manganese beds at Manuels, Topsail, and Smith Point, Newfoundland and those of the imported specimens from Elbingerode, Saxony were made by the writer in the chemical laboratory of the geological department of Princeton University.

Because of the impalpable fineness of grain of many of the manganese-bearing beds, the petrographical descriptions of certain of the thin sections can deal only with the larger features such as structure, mineral aggregations, and a few of the larger and observable minerals.

The writer feels particularly indebted to Prof. C. H. Smyth, Jr., for many helpful suggestions bearing upon the chemical side of the investigation, and to Prof. G. van Ingen for unpublished information regarding the stratigraphy and palæontology of this region, as well as for the loan of the locality maps and data for the columnar sections which are the results of careful surveys made during the summers of 1912 and 1913. All photographs and microphotographs were generously contributed by Prof. van Ingen to further the presentation of the results of this investigation.

FIG. 1. Map showing manganese localities of southeastern Newfoundland, based on Geological Map of Newfoundland by Murray and Howley.


MANGANESE LOCALITIES
of
S.E NEWFOUNDLAND
after
Murray and Howley, 1907.
by
N.C. DaLe, 1914.
Scale
5 10 15 miles
Legend
Cambrian & Ordovician.
Pre Cambrian
Dikes
Manganese Localities
TRINITY BAY
CONCEPCION BAY
RANDOM
Random Sound
Bonavista Bay
Bacalieu I.
C. St Francis
Gt. Bell I.
Lt. Bell I.
Kelly's I.
St. Johns
Topsail
Manuels
Long Pond
Kelligrew
Brigus
212
219E
219A
219L
Chapel Cove
N.F.L. Railway

Manganese Localities
N
N.F.L. Railway
Placentia
Ship Cove
CENTIA BAY

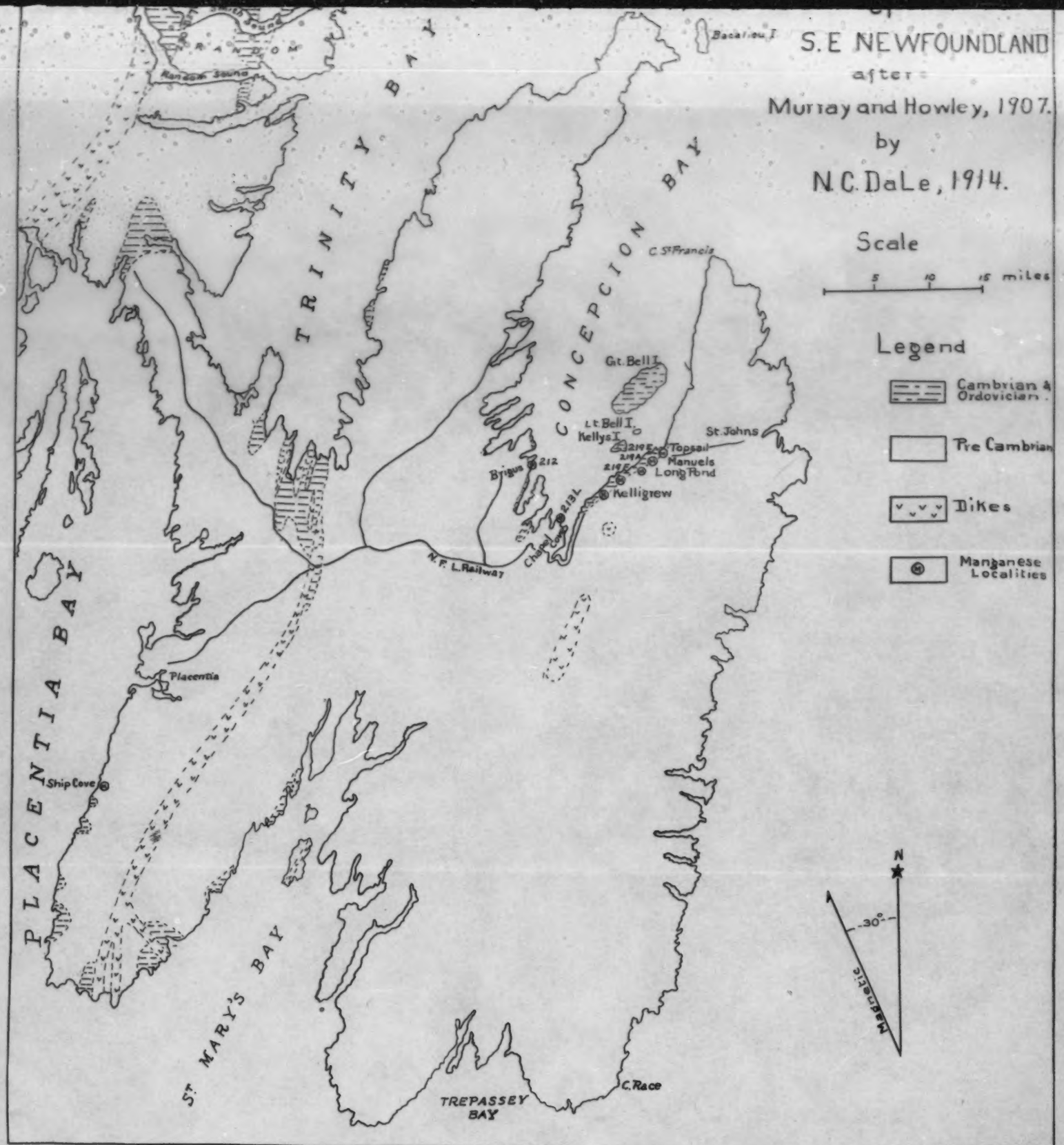


FIG. 1. Map showing manganese localities of southeastern Newfoundland, based on Geological Map of Newfoundland by Murray and Howley, 1907.

II. GENERAL GEOGRAPHIC AND GEOLOGIC RELATIONS OF THE MANGANESE DEPOSITS OF SOUTHEASTERN NEWFOUNDLAND.

Geographic Relations.

The manganese deposits here considered are located in the southeastern part of Newfoundland in the vicinity of Topsail, Manuels, Long Pond, Chapel Cove, and Brigus on Conception Bay, and at Smith Point on Trinity Bay. Manganese is also said to occur near Ships Cove, Placentia Bay. The accompanying map, Fig. 1, shows the approximate location of these deposits.

General Geology.

The sedimentary rocks of this area are included in the Cambrian and Ordovician systems and may be seen on the map (Fig. 1) to occur as irregular patches, the Ordovician composing the larger islands of the bays and the Cambrian occurring as irregular and widely separated fringes resting on the pre-Cambrian of the mainland. The whole series consists almost wholly of shales and thin-bedded sandstones with some limestones, and in the base of the lower Cambrian an occasional conglomeratic bed.

The iron ores of Great Bell Island are Arenig while the manganese and their associated green and red shales are of late lower Cambrian.

Wherever the Cambrian strata have been found in contact with the pre-Cambrian an unconformable relationship exists. The pre-Cambrian rocks of this area as classified by Dr. Walcott (2:219) and by Messrs. Murray and Howley (18:141–154) respectively are as follows:

	Walcott	Murray and Howley
Avalonian	Random	
	Signal Hill	Avalonian
	Momable	
	Torbay	
	Conception	Huronian
	Laurentian	Archaean

The Avalonian and Huronian of Mr. Howley represent a thickness of 12,370 feet. A later unpublished estimate of 18,250 feet has

been made by Mr. A. F. Buddington, who is studying the pre-Cambrian rocks of this region. A brief description of these formations at this time will be necessary for a comprehensive view of the Newfoundland manganese deposits.

Laurentian: The rocks of this formation are in great part gneissic and granitoid, and are probably the oldest rocks of the area.

Huronian: This formation, which is equivalent to the "Conception" of Dr. Walcott, consists principally of the Conception slates which are of tufaceous marine origin. They are intruded by bosses and dikes of granite, diorite, monzonite, and gabbro, and contain basaltic and rhyolite flows. The Conception formation was estimated by Murray and Howley to have a thickness of 2,950 feet.

Torbay: This formation consists of about 3,300 feet of green and purple slates and argillites.

Momable: An estimated thickness of 2,000 feet of brown and black sandy shales overlies the previous formation.

Signal Hill: Red and green sandstones, conglomerates, shales, and arkoses largely of continental origin comprise this formation, the thickness of which is about 9,000 feet according to an unpublished estimate by Mr. A. F. Buddington.

Random: About 1,000 feet of green and red sandstones and white quartzites with occasional basalt flows comprise this series.

Murray and Howley in their report of 1868 for the Geological Survey of Newfoundland describe the general structural features of the Avalon Peninsula as follows:

"The region in question, in particular, and probably the whole island in general, seems to be arranged in an alternation of anticlinal and synclinal lines, independent of innumerable minor folds, which preserve throughout a remarkable degree of parallelism, pointing generally about N-NE and S-SW from the true meridian, corresponding with the strongly marked indentations of the coast as well as the topographical features of the interior. One such great anticlinal form occurs within the region examined this year, with a corresponding synclinal; the axis of the former was found to be more or less overlaid unconformably by rocks containing fossils of Lower Silurian age, none of which were of less remote antiquity than such as are attributed to the horizon of the upper Potsdam group."

"The axis of this anticlinal runs in a moderately straight line from Cape Pine on the south coast to that part of the Peninsula and coming up from below the Intermediate Series, occupies more or less of the surface from the vicinity of the Renew's Butterpots to the shores of Conception Bay be-

tween Holyrood and Manuels Brook. The newer or Great Intermediate Series which flanks this Laurentian Nucleus, was found on the Peninsula of St. Johns and Ferryland to show a general dip to the eastward although making many minor undulations; while on the Peninsula between Conception and Trinity bays the inclination is reversed, being nearly uniformly westerly, making many repetitions of the same strata however, as on the opposite side of the fold. Corresponding with this great anticlinal, the measure of the Intermediate rocks, as seen at parts of the eastern coast of Placentia Bay, appear, by the generally eastern dip which they present, to indicate the axis of a synclinal trough to run from Trinity Bay in the direction of St. Mary's Bay."

As structural work of a reconnaissance nature only has thus far been published in reference to Newfoundland it is hoped that this most interesting phase of geology of the island may be investigated in the near future. The following locality descriptions will take up briefly these smaller structural features which may serve as a clue to the more general structures of the entire manganese area.

III. GENERAL STRATIGRAPHY

There is very little published information regarding the general stratigraphy of the region under consideration but a few observations made while studying the individual manganese deposits and other information verbally communicated by Prof. van Ingen may be of interest at this point.

One of the most striking features of the manganese deposits is their occurrence at the same horizon in shales of late lower Cambrian age at widely separated points on Conception and Trinity Bays. At each deposit, the manganese zone was found to occur below the Paradoxides zone. At Manuels in the shales directly below the manganese nodular beds, heads of Protolenus harveyi (oral communication by G. van Ingen) were found so that in all probability the manganese beds may be included in the Protolenus zone of Matthews (16: 101–153).

By referring to the columnar sections (Figs. 2, 36, 42, and 44) it is readily seen that the sediments consist largely of shales and limestones and that there is a very decided increase in the total thickness of the beds from Manuels where there are 215 feet between the bottom of the Paradoxides zone and the top of the pre-Cambrian to Smith Point, Trinity Bay, where over 1,000 feet intervene between

the Paradoxides zone and the pre-Cambrian. From the bottom of the Paradoxides zone at Smith Point to the top of the Smith Point limestone according to a calculation based upon a careful stadia transit survey of the shore line (Fig. 43) there is a thickness of 546 feet. The total thickness in the number of limestone beds varies from a few feet at Manuels to 100 + feet at Smith Point. The thickness of the shales at Manuels below the Paradoxides zone is about 200 feet while the thickness of the shales at Smith Point within the corresponding limits is over 400 feet, on the assumption that the Smith Point limestone of Trinity Bay corresponds to that limestone of the Manuels section which is just above the basal conglomerate.

The increase in total thickness of the number of beds from the east shore of Conception Bay to the west shore within the corresponding limits would indicate a deeper portion of the Cambrian sea when the sediments were being deposited. The fact that sediments found below the Smith Point limestone on Trinity Bay are not represented at Manuels would indicate that sedimentation had been going on for a longer time in the western portion of the basin than in the eastern. Whether there actually was a greater amount of sedimentation in that portion of the basin remains to be investigated.

As very little information is at hand with regard to the area of the Cambrian rocks, it is quite out of the question for the writer to attempt to outline the area once occupied by the Cambrian Sea in southeastern Newfoundland. Moreover, it is likewise impossible for the writer to outline the original manganese area as it looked in early Cambrian times. If manganese occurs on the eastern shore of Placentia Bay, as all descriptions of that occurrence seem to indicate, it would seem that the original area of the manganese was approximately 200 or 300 square miles, assuming a more or less oblong shape for the deposit.

Although the basal conglomerate at Manuels is evidence of a definite shore line for the Cambrian sea at that part of the basin, there is also evidence at the other localities examined, where, however, the basal conglomerate is not found in any such large development. There are littoral pre-Cambrian contacts at Topsail, Chapel Cove, and Brigus; all with typical shore deposits.

IV. DETAILED DESCRIPTIONS OF LOCALITIES

MANUELS.—Manganese is found as thin jasper-like bands of green and brown color, as nodular beds, and as argillaceous and calcareous beds interbedded with green and red shales of late lower Cambrian age. This mode of occurrence is very well shown in Manuels brook close by the village of Manuels. The geographic, geologic, and stratigraphic relations are shown in Figs. 1–3. The Cambrian at Manuels consists in the main of shales with thin bedded sandstones with conglomerate and thin limestones at its base and the sediments show practically no metamorphism throughout the series. The strike of the beds is N 82 E (true meridian) and the dip is 10 N. One of the best unconformable contacts in the manganese area is that in Manuels brook at Manuels where the basal Cambrian conglomerate lies upon the Huronian. For a more intimate acquaintance with the manganese occurrence a somewhat detailed description of the stratigraphy, lithology, mineralogy and petrography of the manganese beds and their associated strata will be necessary and therefore the individual beds of the section (Fig. 2) will be described in stratigraphical order.

210 A 1, Basal Conglomerate. The base of the Cambrian at Manuels is made up of coarse conglomerate, eighteen feet in thickness, consisting in the main of boulders and pebbles of igneous character. These boulders at the bottom of the bed, where the base of the Cambrian lies unconformably upon the Huronian, measure in some instances twelve feet in diameter, but they diminish in size toward the top to an inch or less. The matrix, of an arenaceous nature toward the bottom, grades into a more calcareous one at the top where the overlying stratum is a limestone.

219 D 1, limestone. This bed is a bluish fine-grained to pebbly argillaceous limestone of about 3 feet in thickness. The pebbles averaging a fraction of an inch in diameter are angular to subangular in shape and appear to be of igneous rocks. Pteropod shells chiefly of the genus *Coleoloides* abound. Microscopic examination proves this rock to be a semi-crystalline, fine to locally coarse grained limestone. The texture is very suggestive of organic forms, being an aggregate of elliptical bodies, possibly algal concretions [or "copro-

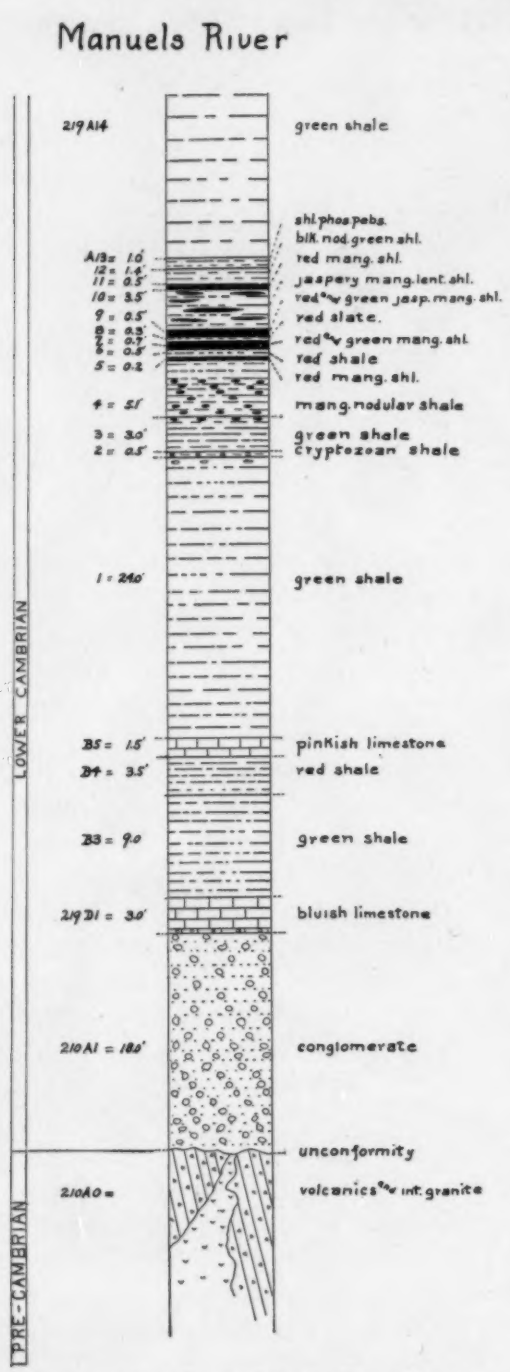


FIG. 2. Columnar section showing the details of the manganese zone in the Lower Cambrian of Manuels brook, 219 A and B.

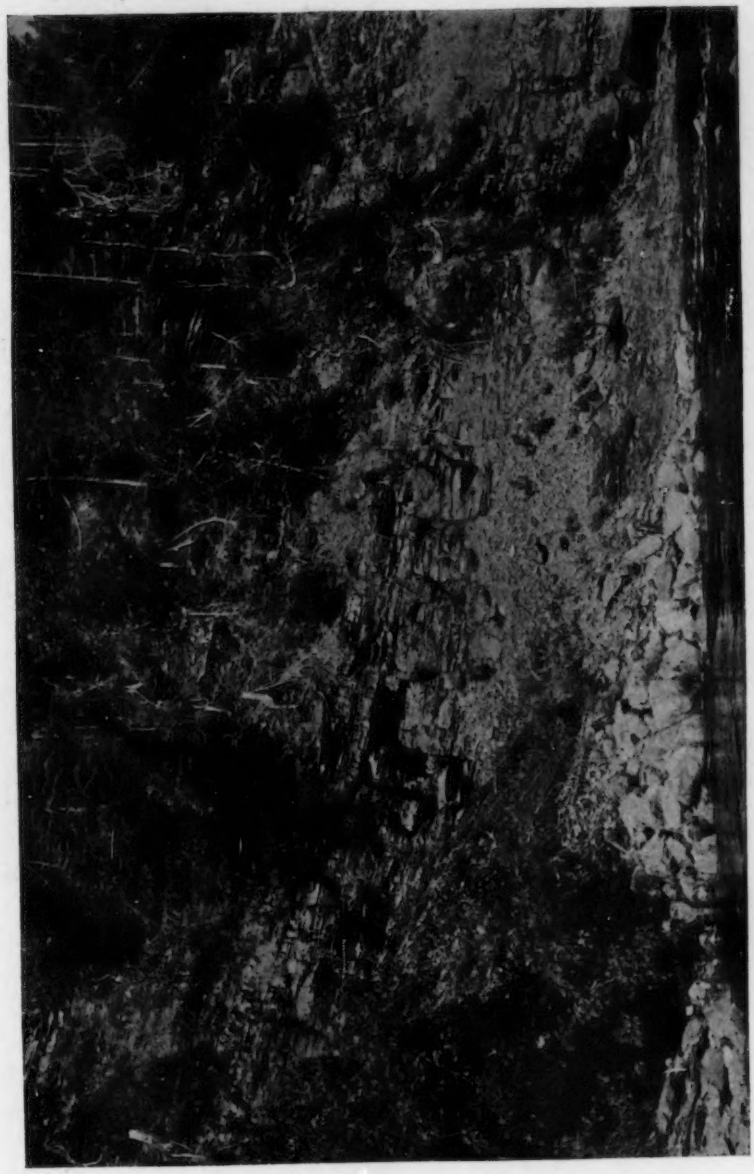


FIG. 3. View of outcrop of manganese zone of late lower Cambrian age in left bank of Manuels brook.

lite ooze" similar to that described by Philippi from off the Congo mouths—G. van Ingen]. These bodies contain aggregations of carbonate material, probably calcite, which have no definite orientation. The section abounds with pteropod shell fragments, partially replaced with calcite. Calcite and carbonate material comprise the greater portion of the section but quartz occurs as infrequent local segregations and as irregular grains. Pyrite and hematite, as well as a few pink and brown stained areas which are possibly secondary products of manganese and iron, are sparingly present. No analysis was made of this rock but with the sodium carbonate and potassium nitrate bead test a manganese reaction was obtained. This bed is a bluish argillaceous manganiferous limestone.

219 B 3, overlying the limestone, is a brownish weathering olive green shale.

219 B 4 is a bed of red shale, the upper surface of which seems to be limey. The upper 2 inches of this bed has a wavy structure and is somewhat greenish in color. Microscopically the bed is found to be a hematitic shale with occasional grains of quartz and thin rectangular laths of feldspar. Magnetite and pyrite are found as irregular grains in sparing amounts.

219 B 5. With a sharp contact, the red shale is overlain by a 1.5 foot thick bed of nodular and pebbly reddish blue limestone. Because of marked lithological differences this bed has been divided into four smaller subdivisions which are lettered **a, b, c,** and **d.** Subdivision **a** consists of about 2 inches of green shale which is slightly calcareous. Subdivision **b** is a compact pinkish limestone containing pinkish or reddish mineral disseminations and occasional fragments of hyolithid and brachiopod shells. Microscopically this limestone is somewhat granular and crystalline, with calcite as the dominant anisotropic mineral. Quartz occurs occasionally. Hematite as an impalpable dust or pigment is abundant, bordering hyolithid fragments or as irregular accumulations. A fragment of probably organic substance with a cellular structure is a conspicuous feature of the slide. Sponge spicules replaced by calcite are noticeable.

Subdivision **c** differs not very much from the two members described but is nodular or pebbly and much more fossiliferous. Micro-

scopically this rock is a very fine grained semi-crystalline limestone. Calcite, frequently twinned, is the dominant mineral with quartz and chlorite in secondary importance. Barite occurs as occasional small and large irregular grains. Hematite is found bordering calcite grains and fossil fragments or replacing them, and as irregular accumulations. Pyrite is found occasionally. Certain nodular or pebbly forms, isotropic under crossed nicols, are, because of their fineness of grain, of an indeterminable nature.

A very noticeable feature of this section is the diversity of *Hyolithes* forms, some elliptical and concentric and others circular, either entirely or partially replaced by calcite or hematite. The circular forms measure .287 mm. in diameter (Fig. 4, Slide 250).

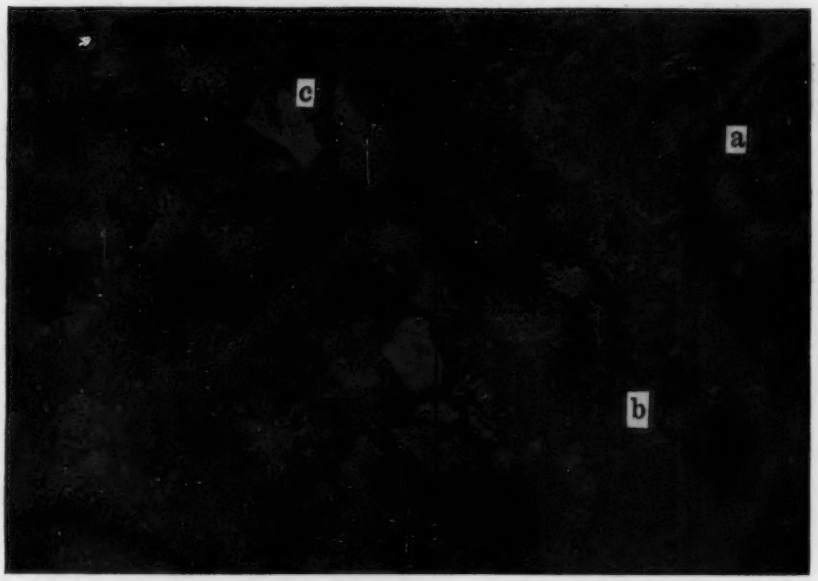


FIG. 4. Microphotograph of limestone, 219 B5c; slide 250; enlarged 22 diam. a, hyolithes with calcite and chlorite; b, calcite; c, quartz.

219 B 5d. The upper subdivision of this bed is of interest mainly on account of the mineral associations in the large nodules on its surface. Differential erosional effects between the limestone and nodule have resulted in a greater conspicuousness of the more resis-

tant nodule. The nodules, measuring as much as 6 inches in diameter, consist largely of argillaceous material, jaspery concentric bands, blades of barite, pyrite and some disseminated manganiferous and ferruginous carbonate minerals which are surrounded by dark areas. These latter are probably manganese oxide zones due to the alteration of a manganiferous carbonate.

Under magnification these nodular portions are roughly concentric and laminated in structure, with laminations red and green in color, and of fine and coarse grain. An oölitic structure, but with the spherules poorly formed, is found in combination with the banded structure. Calcite occurs as somewhat elongated crystals and is the dominant mineral. Wherever the calcite presents the peculiar elliptical and circular shapes mentioned on page —, an organic origin is immediately suggested (Fig. 5 and 6, Slide 254).

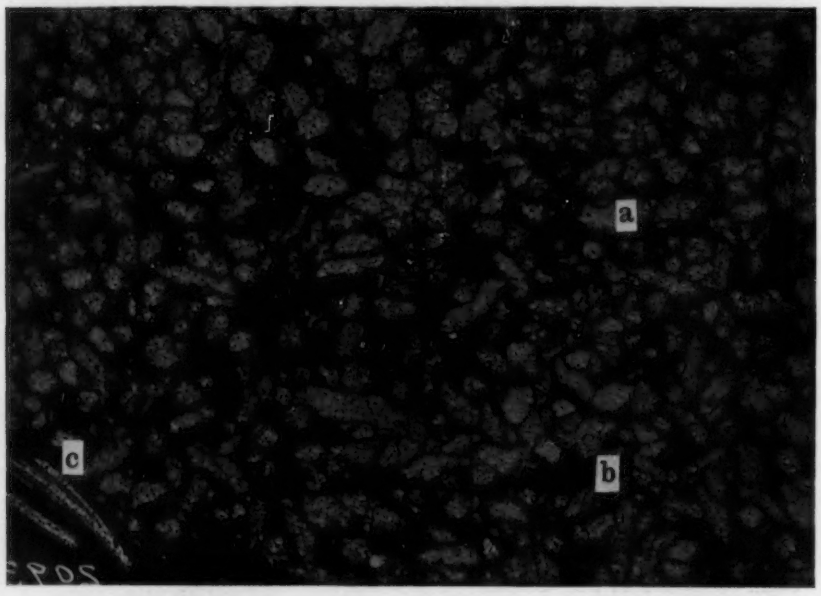


FIG. 5. Microphotograph of limestone, 219 B5d; slide 254; enlarged 22 diam. **a**, elliptical calcite aggregations; **b**, chlorite; **c**, hyolithes.

Quartz is found as irregular grains and aggregations. Barite occurs only sparingly. Among the opaque minerals, pyrite sometimes alter-

ing to limonite, is most conspicuous and occurs as large irregular grains and areas surrounding fossil fragments and associated with

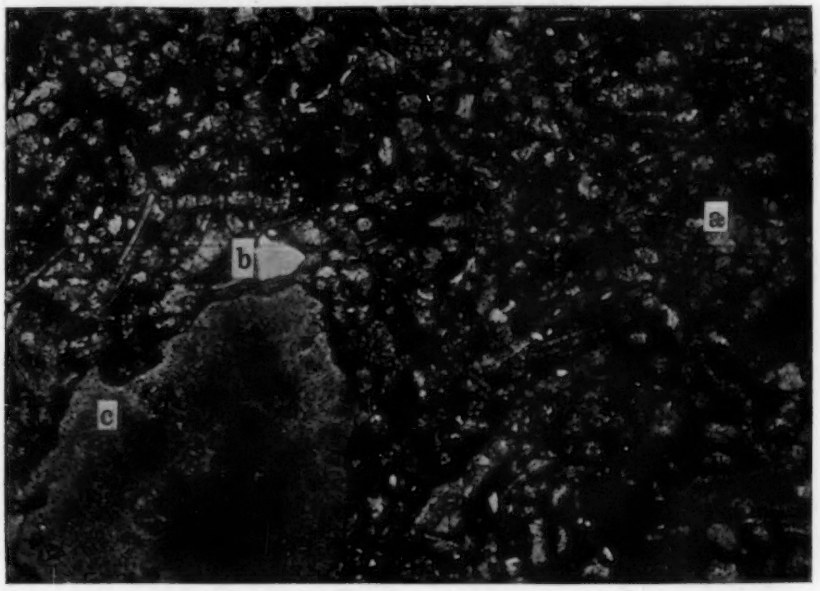


FIG. 6. Microphotograph of limestone, 219 B5d; slide 254; enlarged 22 diam. a, calcite; b, quartz; c, phosphatic? nodules.

more calcareous portions. Hematite (Fig. 7, Slide 257) is found in the more jaspery or laminated areas as irregular grains, aggregations, and spherules associated particularly with the green area which for the most part is of an indeterminable character. Veins of calcite are found cutting the nodule. As in the layer above, there are found in this one (Fig. 8, Slide 253), certain semi-isotropic nodular areas or pebbles which are partially chloritized. It is very possible that these nodular or pebbly areas are similar to the phosphatic nodules of 219 A 13 to be described later. These alter to carbonate locally. Among the organic remains are fragments of shells, hyolithes, trilobites, and sponge spicules, which in part show carbonate and chloritic replacement (Fig. 5, Slide 254, and Fig. 7, Slide 257).

219 A 1. Disconformably upon the above described nodular limestone there rests about 34 feet of a hard, fissile, green shale. About

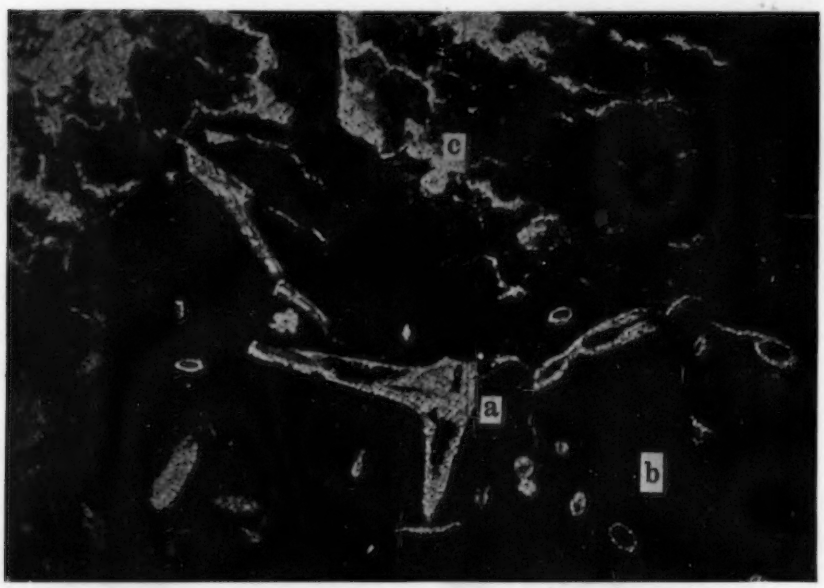


FIG. 7. Microphotograph of sponge spicules, 219 B6a; slide 257; enlarged 22 diam. **a**, sponge spicule; **b**, hematite; **c**, calcite.

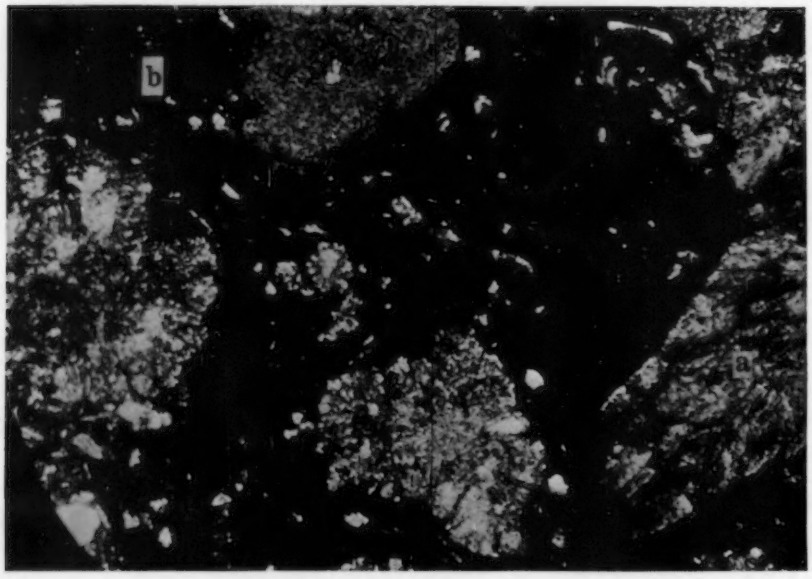


FIG. 8. Microphotograph of limestone, 219 B5d; slide 253; enlarged 22 diam. **a**, calcite; **b**, phosphatic? material.

5 feet above the limestone there are thin seams full of comminuted fragments of small *Lingulella,* and *Hyolithes* shells. The upper part of this shale is conspicuous because of the conchoidal fracture with which it breaks and the presence of local aggregations of small subspherical black nodules some of which show pinkish centers of some fine-grained minerals such as rhodochrosite or manganiferous calcite. MnO_2 occurs as small dots or as dendritic areas on the fracture planes. Microscopically, this is a chloritic micaceous shale containing sparingly, among the visible minerals, irregular grains of plagioclase, quartz, pyrite, magnetite and limonite in descending order of abundance.

219 A 2 is a nodular shale bed of .5 of a foot in thickness and forming the sloping surface over which the stream runs. This bed is noteworthy because of the Cryptozoon colonies showing on the surface (see Fig. 10).

219 A 2a, the lower portion of this bed, is a green shale containing frequent small subspherical nodules and disseminations of a pink carbonate which effervesces freely and is in all probability a manganiferous calcite similar to the pink nodules analyzed (see page 395).

219 A 2b is the Cryptozoon shale bed and contains roughly concentric or zonal structures measuring 1½ inches in diameter, irregular and sub-spherical nodules measuring 1 inch in diameter, and intercalated lenses of manganiferous calcite. These nodular and Cryptozoon structures weather brown. Scattered through the bed, particularly the shaly portions, are blades of barite.

Microscopic examination of this Cryptozoon bed brings out nothing which can be said to be of an organic structure. What structure there is may be characterized as broken veinous, concentric and laminated. The texture in great part is crystalline. The greater portion of one of the nodules consists of calcite and carbonate. Barite occurring as long blades is determined principally by the two cleavages, c and m, its birefringence greater than quartz and its biaxial + character. Chlorite either alone or in combination with carbonate is found replacing barite. Calcite or carbonate occur as irregular masses or as rudely formed or incipient spherules. Hematite occurs in the banded portions as more or less massive bands interlaminated with chlorite or as rudely formed spherules in the

FIG. 9. Details of lower portion of manganese zone in Manuels brook.

FIG. 10. Photograph of upper surface of Cryptozoon bed, 219 A2, in left bank Manuels brook.

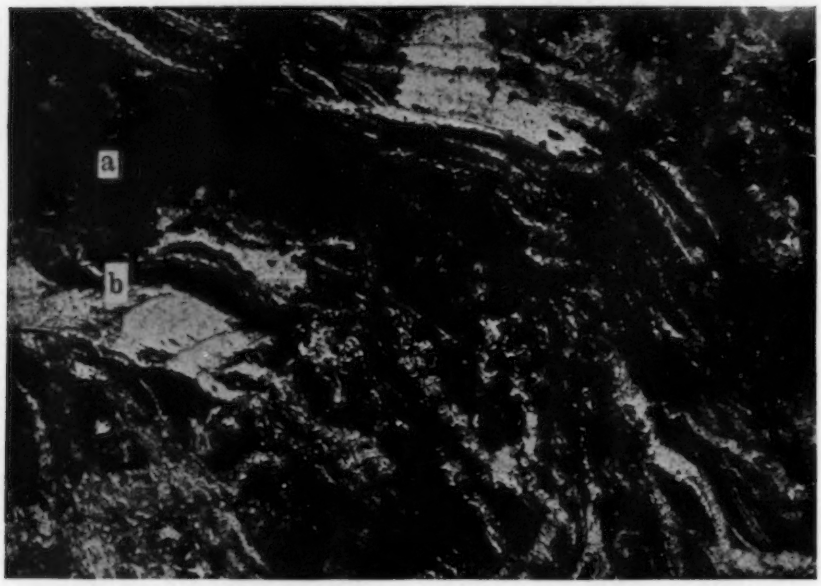


FIG. 11. Microphotograph of section of Cryptozoon nodule, 219 A2; slide 292; enlarged 22 diam. **a**, ferruginous band; **b**, calcite.

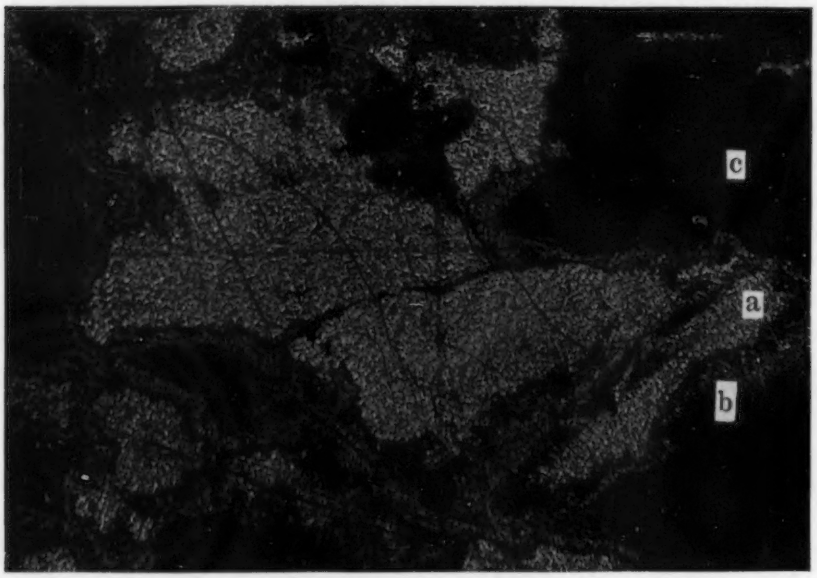


FIG. 12. Microphotograph of Cryptozoon nodules from 219 A2, showing barite being replaced by chlorite; slide 292; enlarged 22 diam. **a**, barite; **b**, chlorite; **c**, ferruginous and calcareous shale.

ground mass. These spherules measure as small as 9 microns in diameter but have an average diameter of between 30 and 40 microns (Fig. 11 and 12, Slide 292).

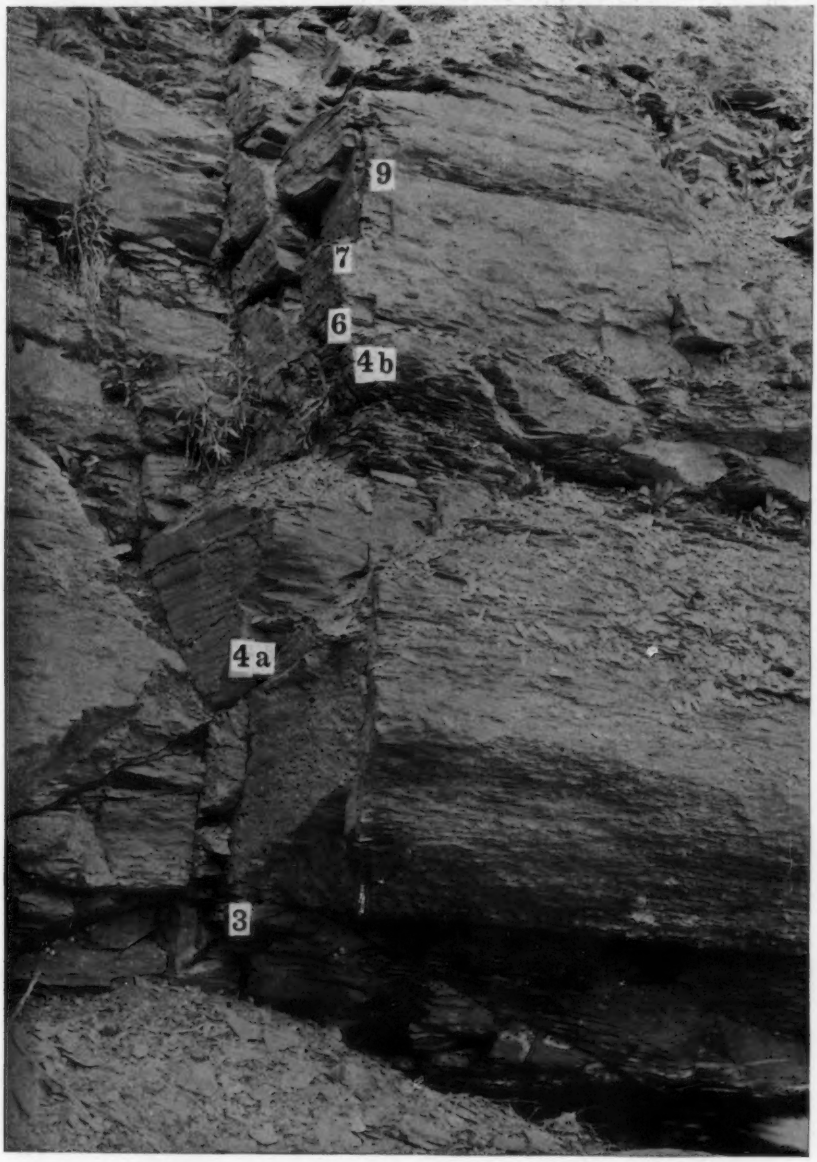


FIG. 13. Middle portion of manganese zone in Manuels brook. The numbers are those of the section.

The paragenesis of minerals within the nodules is as follows: Calcareous or carbonate material with probably synchronously formed hematite, barite veining, chloritization replacement, and finally calcite as vein or replacement material.

219 A 3 is a green shale bed, 3 feet in thickness, lying conformably above the Cryptozoon nodular bed. For the most part this bed consists of a hard fissile green shale which breaks with a conspicuous

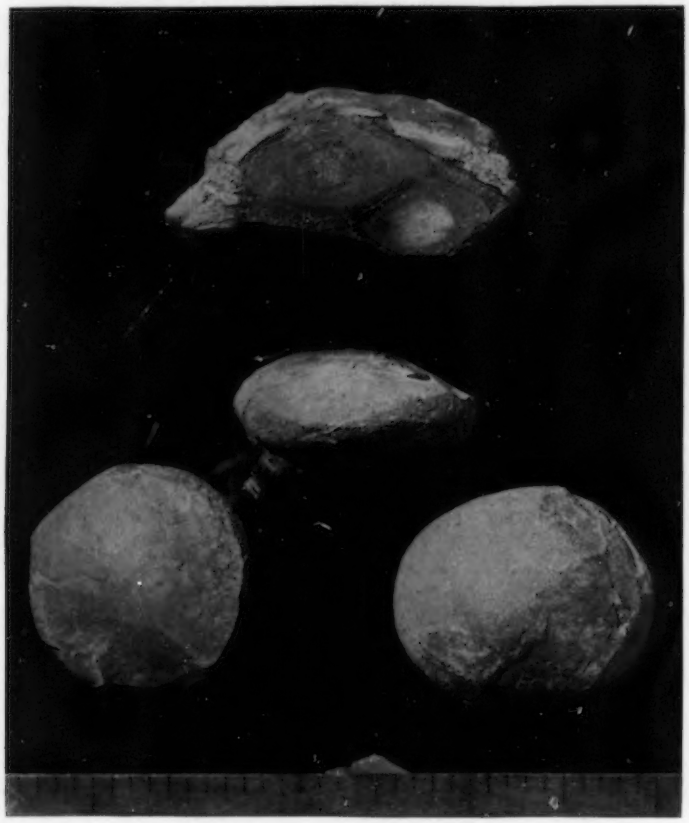


FIG. 14. Photograph of manganese carbonate nodules extracted from shale 219 A4, natural size. Top, side and sectional views.

conchoidal fracture. 3 inches above the Cryptozoon bed is a layer containing fragments of trilobites which according to Prof. G. van Ingen are probably to be identified as *Protolenus harveyi*. Barren

green shale overlies this fossiliferous layer and this in turn is followed by nodular green shale containing manganiferous calcite nodules, a description of which is given in connection with the following bed.

FIG. 15. Photograph, natural size of ground and polished horizontal section of shale containing manganese carbonate nodules from 219 A4.

219 A 4 is a conspicuous rhodochrosite and manganiferous calcite nodular bed and may be considered the base of the manganese zone at Manuels (Fig. 13). Structurally this is a nodular and oölitic bed, the former structure conspicuously observable macroscopically, and the latter, though not so well defined a structure, observable microscopically. The entire bed measures 5.1 feet in thickness and is divisible into two members, **a** and **b**. The lower member, **219 A 4a** is a predominantly nodular reddish green shale while the upper division or **b** member is not so nodular.

The nodules of **219 A 4a** are discoidal in shape and vary in diameter from ⅛ inch to 1½ inch, with an average of about 1 inch and a thickness ranging from ⅛ inch to ½ inch. The longer diameters of the nodules lie in the plane of the bed. Where the nodules are very numerous or crowded they are found intergrown with or overlapping each other. Specimens ground and polished often show a lemniscate formed by two nodules (Figs. 14 and 15). In color they are for the most part green, but may have greenish, white, or pink central cores. Cross sections of the nodules reveal a distinct zonal arrangement with spherical central cores surrounded by concentric

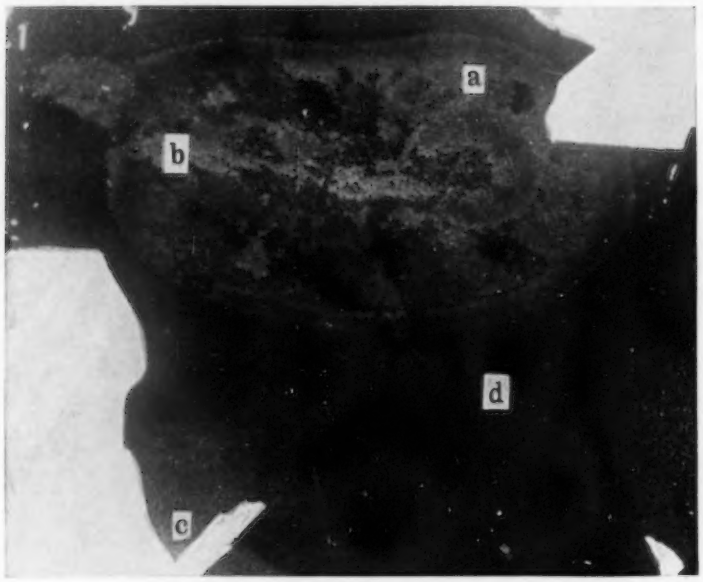


FIG. 16. Microphotograph of manganese carbonate nodule from 219 A4a; slide 288; enlarged 6 diam. **a**, carbonate of manganese, lime and magnesia; **b**, barite; **c**, barite replaced by chlorite; **d**, shale.

shells conforming to the shape of the nodule. The grain of the nodules is usually exceedingly fine, impalpable or crystalline. The pinkish cores are usually crystalline and respond to the HCl test quite readily, indicating some carbonate mineral. By analysis the green nodules are found to consist essentially of rhodochrosite (see Anal. *B*, page 395), while the pinkish crystalline mineral occupying

the centers of the nodules or occurring as intercalated lenses or nodules in the nodular bed is found to be essentially a maganiferous calcite (see Analysis *C*, page 395).

FIG. 17. Microphotograph of coalescing nodules from 219 A6c; slide 243; enlarged 4 diam. **a**, carbonate of manganese, etc.; **b**, oölitic shale.

Further macroscopical examination of the nodules shows the presence of barite blades within the central portions of the nodules or disseminated throughout the nodule or its shaly matrix. The characteristics which determined the barite are its c and m cleavage, its hardness of 2 and its diaphaneity. Its optical properties confirm it microscopically. Pyrite is found sometimes completely surrounding central cores as irregular and continuous grains. The surfaces of the nodules usually are covered with minute pink or reddish disseminated grains which upon microscopic examination are found to be hematitic spherules.

Thin sections of these nodules, on the whole, are not satisfactory for microscopical work because of the almost impalpable fineness of the grain. However some of the larger features may be of interest and importance. The structure is nodular and concentric and some of the concentric shells are oölitic. In all the thin sections of nodules the most conspicuous feature is the zonal arrangement of crystalline and indeterminable portions. The crystalline parts usually occupy the centers of the nodules while the impalpable or indeterminable areas are arranged around the centers (see Fig. 16, Slide 288). However some of the cores consist of indeterminable material. The zones are sometimes marked off from each other by more or less sharp contracts as brought out by a difference in shade of color or by an apparent difference in grain (Figs. 17, and 18).

The exterior zones merge imperceptibly into the shale, a fact which has some genetic significance.

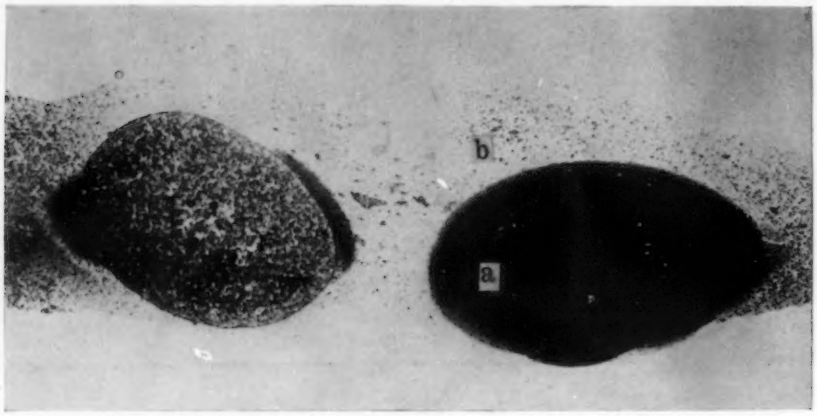


FIG. 18. Microphotograph of two manganese carbonate nodules from 219 A6c; slide 237; enlarged 8 diam.

An incipient oölitic structure with spherules of hematite is common to the outer zones of the nodule and shaly matrix. The spherules do not as a rule show any well-developed zonal structure nor are they of very regular form. They vary in diameter from 6 microns to 77 microns and have an average diameter of about 24 microns. Not infrequently the spherules consist of both carbonate and hematite, the former preserving a radiating structure and abounding in the more calcareous portions of the specimen, while the hematitic spherules are more common in the shaly parts.

Among the determinable minerals are calcite, which occurs as anhedral grains of variable dimensions in small crystalline areas, in veins, or as replacement material after organic remains such as sponge spicules, etc. Carbonate material for the most part specifically indeterminable makes up the greater part of the slide. Barite is found occupying the more central portions of the nodule in some sections. Quartz as irregular grains occurs only in sparing amounts. Pyrite is present as large and small irregular grains and masses.

The analyses of the green and pink nodules are as follows:

ANALYSIS *B*.

Green Nodules.

SiO_2	10.31
Fe_2O_3	7.35
Al_2O_3	3.68
MnO	31.76
CaO	10.46
MgO	1.80
$BaSO_4$	6.43
H_2O	2.85
CO_2	25.31
	99.96

ANALYSIS *B* 1.

Recalculation.

$MnCO_3$	39.56
MnO	7.30
$CaCO_3$	18.61
$MgCO_3$	3.79
SiO_2	5.94
$BaSO_4$	6.29
H_2O	1.51
Fe_2O_3	7.35
$2H_2O \cdot Al_2O_3 \cdot 2SiO_2$	9.17
	99.52

ANALYSIS *C*.

Pink Nodules.

SiO_2	5.14
Fe_2O_3	1.40
Al_2O_3	1.64
MnO	20.49
CaO	32.92
MgO	.01
H_2O	1.65
CO_2	36.77
	100.02

ANALYSIS *C* 1

Recalculation.

$CaCO_3$	58.05
$MnCO_3$	29.32
MnO	2.34
SiO_2	3.78
Fe_2O_3	1.40
H_2O	1.06
$2H_2O \cdot Al_2O_3 \cdot 2SiO_2$	4.07
	100.02

The pinkish crystalline mineral which exhibits a rhombohedral cleavage, has a hardness of about 3, effervesces freely with HCl acid, and, with the above composition, is essentially a manganiferous calcite. The excess MnO probably exists as a peroxide of manganese as indicated by the considerable amount of chlorine which was given off while the sample was being digested with HCl acid. As no thin sections were made of this specimen no petrographic confirmations can be made.

The upper subdivision of 219 A 4 (**219 A 4b**) is a greenish and reddish nodular shale bed measuring 2.9 feet in thickness and divisable into three roughly distinct portions. The lower part, **219 A 4b 1** is a greenish red shale overlaid by a reddish shale with occasional small nodules measuring about ¼ inch in diameter (Fig. 13, and 19).

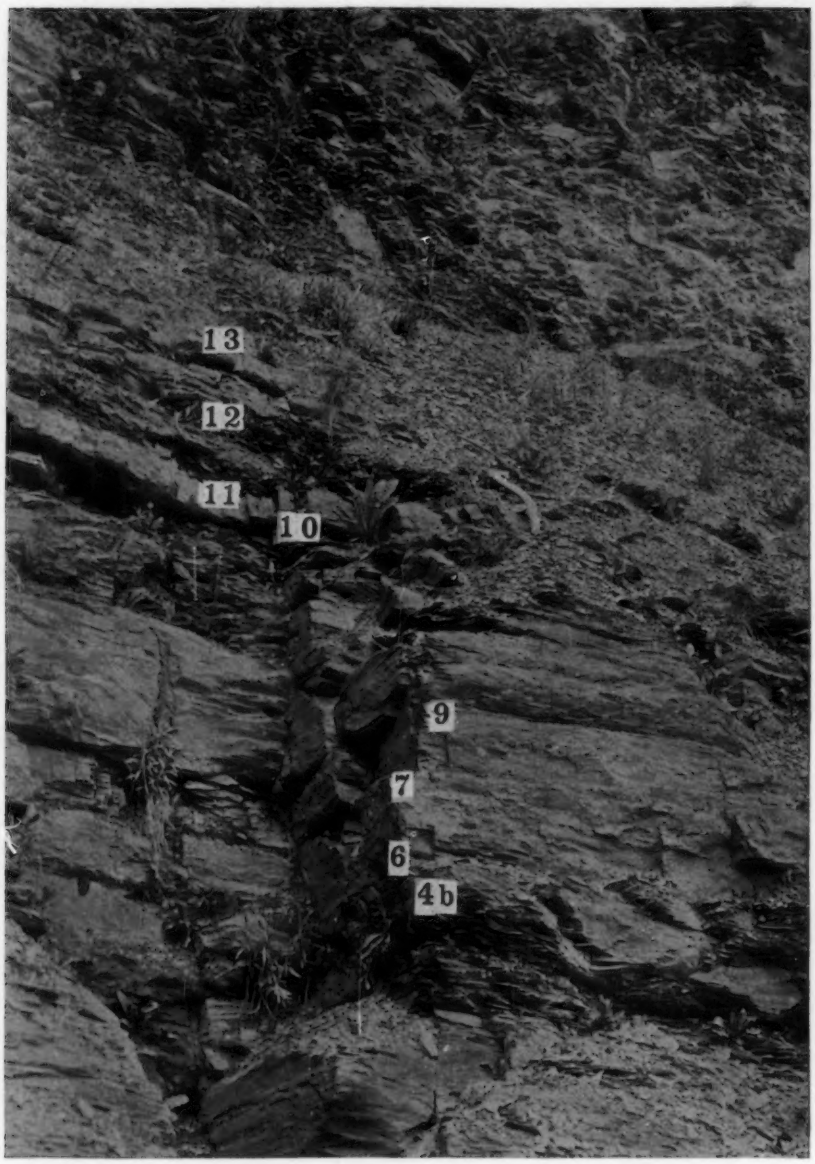


FIG. 19. Middle and upper portions of manganese zone in Manuels brook.

FIG. 20. Photograph of polished vertical section of banded manganese carbonate-oxide ore, 219 A7, slightly enlarged (1.8 diameters). **a**, green band; **b**, red band.

Under the microscope a thin section of this bed reveals hematite in the form of a pigment and as grains and ill-formed spherules, while local areas of carbonate are found. The upper member of this bed, **219 A 4b 3** is a red shale containing small subspherical and discoidal nodules quite similar to those described in detail above.

219 A 5 is a nodular ferruginous shale which is calcareous and manganiferous. The shaly structure and the manganese are brought out in a conspicuous way through weathering; the manganese by the black discoloration in evidence as one of the derived oxides. This bed has a thickness of .2 of a foot but thins and thickens, presenting a lenticular appearance. The nodules, or possibly pebbles, are subspherical in form, dark green in color, and of impalpable fineness of grain. They resemble those already described in connection with the

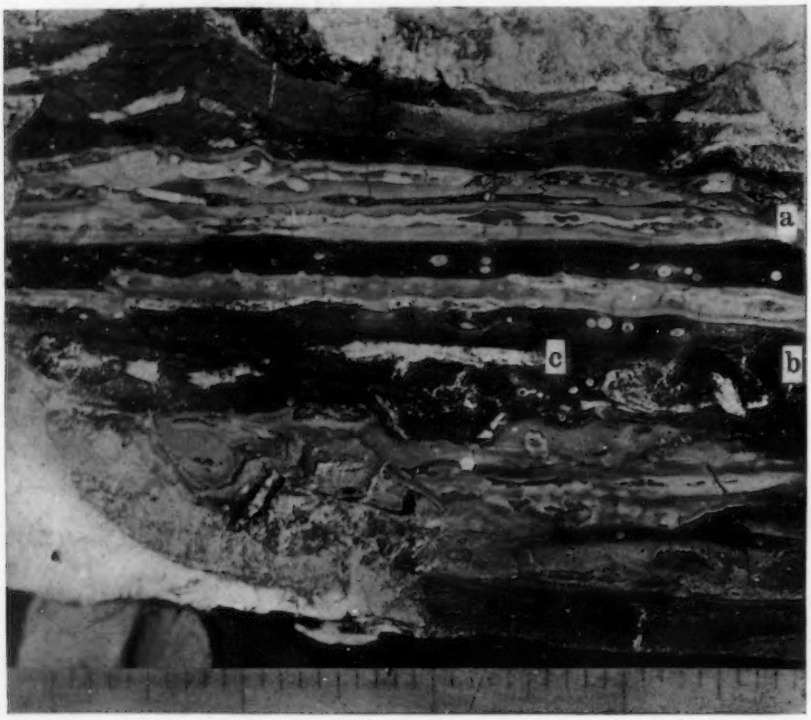


FIG. 21. Photograph of polished vertical section of banded manganese carbonate-oxide ore from 219 A7, natural size. **a**, green band; **b**, red band; **c**, barite.

219 B 5 limestone and those about to be described in beds 219 A 11 and 219 A 13, and are probably phosphatic pebbles in compostion. The minerals in evidence in this bed are hematite, calcite, and barite. This bed is undoubtedly a manganiferous bed as shown by the oxi-

FIG. 22. Photograph of vertical polished section of banded manganese carbonate-oxide ore from 219 A7, natural size. **a**, red band; **b**, brown band.

dized weathering products. The bed as a whole resembles 219 A 11 which to all appearances is suggestive of mineralized reworked material.

219 A 6 is somewhat fine-grained and gritty red shale, measuring 0.4 to 0.5 of a foot in thickness.

219 A 7 is the main manganese-bearing bed, measuring .7 of a foot in thickness. This bed is of more than usual interest in that the manganese occurs as primary carbonates and oxides in the form of thin jasper-like bands of green and light chocolate brown color, and as lenticles, and nodules. Interlaminated with the jaspery bands are reddish bands with manganese essentially in the form of an oxide and a carbonate (Fig. 20, 21, and 22). This bed has been divided into three layers, **a, b,** and **c.** The lowermost or **a** subdivision is the reddish band which is essentially a manganiferous shale. It is nodu-

lar with nodules, lenticles, and bands of the green jaspery carbonate and oxide of manganese. Wherever the jaspery minerals occur in the red band, whether as nodules, lenticles, continuous or non-continuous bands, they present or suggest concretionary characteristics. The red bands are locally pyritiferous and barytic. Red shale occupies the greater portion of the bed.

Microscopic examination of this red band brings out very little, other than that it is distinctly hematitic with the hematite occurring as a pigment or as irregular accumulations (Fig. 23, Slide 276).

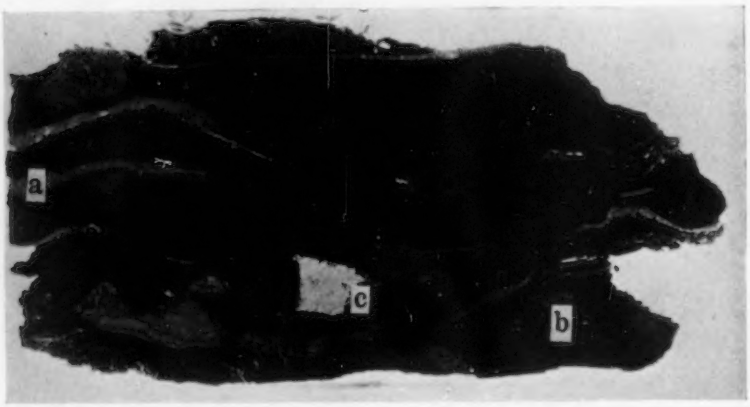


FIG. 23. Microphotograph of banded manganese ore with barite, from 219 A7; slide 276; enlarged 9.5 diam. **a**, red band; **b**, green band; **c**, barite.

The chemical analysis of this band is as follows:

ANALYSIS *E*.

Red Bands.

SiO_2	27.61
Fe_2O_3	4.25
FeO	1.69
Al_2O_3	6.96
MnO	26.05
CaO	9.94
MgO	3.49
P_2O_5	4.71
H_2O	4.73
CO_2	10.57
	100.00

ANALYSIS *E* 1.

Recalculation.

MnO	19.71
$MnCO_3$	10.23
$MgCO_3$	7.25
$CaCO_3$	7.50
$Ca_3(PO_4)_2$	10.31
SiO_2	19.44
H_2O	1.87
$2H_2O \cdot Al_2O_3 \cdot 2SiO_2 + FeO$	19.01
Fe_2O_3	4.25
	99.57

Of most interest in connection with this red shaly band are the jaspery bands of green and brown carbonate and oxide of manganese. Where in bands, they vary from ⅛ inch to 1 inch + in thickness and may be continuous. The contact with the red band may be very even or very undulatory. This wavy character may be present whether the band thickens or thins or is of the same thickness throughout. The brown and green jaspery bands may contain thin laminæ or nodules of other colors.

The green material is characterized by its chalcedonic and somewhat waxy luster, its translucency on thin edges, its hardness of 5 to 6, its specific gravity of about 3.13 (that of the green nodule) and its slight response to HCl.

The chemical analysis of this material is as follows:

Analysis *A*. *Green Band.*	
SiO_2	7.24
Fe_2O_3	3.36
FeO	3.21
Al_2O_3	6.11
MnO	35.53
CaO	11.30
MgO	2.30
H_2O	2.98
CO_2	28.06
	100.09

Analysis *A* 1. *Recalculation.*	
$MnCO_3$	44.39
MnO_2	8.08
$CaCO_3$	20.11
$MgCO_3$	4.21
FeO	3.36
H_2O	.86
$2H_2O \cdot Al_2O_3 \cdot 2SiO_2 + FeO$	18.24
	99.25

The green band so very similar chemically to the green nodule already described in connection with the nodular bed lower down in the series, is in great part a rhodochrosite in composition but has in combination, in descending order of abundance, considerable amounts of calcareous, argillaceous and ferruginous material. Manganese not combined with CO_2 probably exists as some oxide, probably a peroxide, as considerable chlorine was given off by the sample when first treated with concentrated HCl. Other features hardly need any explanation.

Thin sections of this band are very unsatisfactory in that, because of the impalpable fineness of the grain, little can be seen outside of structural features and certain opaque minerals, chiefly hematite.

The brown band differs in chemical composition, in color, and in specific gravity. The color is a light or dark chocolate brown. The specific gravity is 3.32. The chemical composition differs mainly in the higher percentage of manganese, as shown in the following analysis:

ANALYSIS *D*.

Brown Band.

SiO_2	10.23
Fe_2O_3	1.32
FeO	.89
Al_2O_3	4.84
MnO	49.25
CaO	8.11
MgO	3.02
H_2O	1.31
CO_2	21.83
	100.80

ANALYSIS *D* 1.

Recalculation.

MnO	28.93
$MnCO_3$	32.89
$CaCO_3$	14.01
$MgCo_3$	5.90
$2H_2O \cdot Al_2O_3 \cdot 2SiO_2$	11.08
SiO_2	5.40
Fe_2O_3	1.27
	99.48

Members **b** and **c** of bed **219 A 7** differ from the subdivision just described in the greater abundance of jaspery bands in comparison with the red shaly band and they show greater continuity on the whole.

Member **d** consists of green and brown jaspery bands all more or less nodular and interlaminated with the red manganiferous shale. Barite as segregations, disseminated blades, and veins occur infrequently. In the weathered portions of the section this bed is found altering on its more exposed structural planes to the secondary oxides of manganese such as psilomelane, etc.

219 A 8 is a purplish manganiferous nodular shale measuring 0.3 of a foot in thickness. It contains lenticles and discoidal nodules of the green jaspery manganese carbonate (Fig. 24, Slide 284). The noticeable microscopic features of a thin section of this rock are its nodular, oölitic and shaly structures. The spherules, though rudely formed, are of either hematite or a carbonate, the former more closely associated with the green jaspery structures, and the latter with the red shale.

219 A 9 is a manganiferous bed structurally, mineralogically, and, presumably, chemically, analogous to 219 A 7, and measuring .5 of a

foot in thickness. Green discoidal nodules of manganese carbonate and the green, brown and red manganiferous bands similar to those of 219 A 4 are a conspicuous feature of the bed. A thin section from one of the nodules of this bed collected during the summer of 1912 shows, aside from the nodular form, conspicuous zonal and

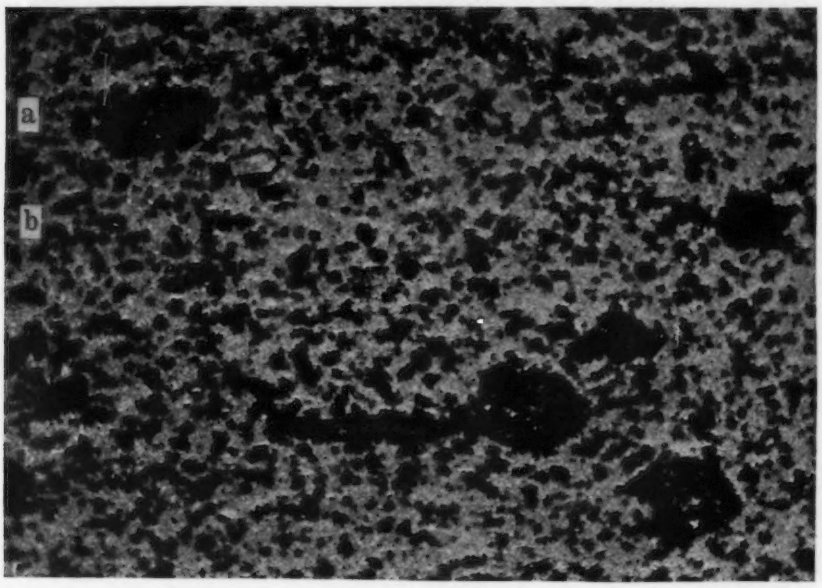


FIG. 24. Microphotograph of red shale from 219 A8; slide 284; enlarged 38 diam. **a**, hematite aggregation; **b**, spherules of hematite.

oölitic structures. For the most part the grain is impalpable, but that of the core is more or less crystalline. There are five pronounced parts consisting of a crystalline innermost core, No. 1, which in a great part is composed of carbonate, presumably that of calcium and manganese though nothing of a definite confirmatory nature could be observed, and 4 successive enveloping shells differentiated from each other by either the presence or absence of hematite, the shade or intensity of color or by fineness of grain. The oölitic character of zones 3 and 5 with spherules consisting in great part of hematite and measuring as small as 12 microns and as large as 90 is very noticeable. Layers 2 and 4 in a great degree consist of

indeterminate material (Fig. 25, Slide 244). Anisotropic minerals in this section are not common but those most noticeable are calcite,

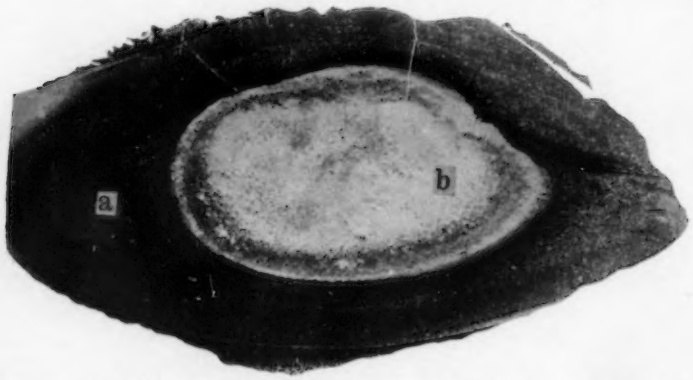


FIG. 25. Microphotograph of nodule, from 210 A7; slide 244; enlarged 4.0 diam. **a**, outer zone of manganese carbonate; **b**, core of crystalline manganese carbonate.

barite, and chlorite, the latter being usually associated with the barite.

219 A 10 consists of 3.5 feet of alternate layers of purple and green shale which contain thin nodules and lenticles of jaspery manganese carbonate, some of which measure 1.3 feet in length and 0.1 feet in thickness. The lowermost subdivision of this bed, **210 A 10a,** is a dark reddish-green heavy nodular and oölitic shale with nodules very similar to those described above. Disseminated minute reddish mineral particles suggesting hematite spherules are found rimming the nodules in some cases. Barite occurs occasionally. Subdivision **b** of this bed is composed of 0.2 of a foot of green and red lenticular manganiferous seams with green jaspery nodules, similar to those in the lower beds, interlaminated with a hematic oölitic shale. Subdivision **c,** measuring 0.5 of a foot in thickness, is a dark gray oölitic and slightly nodular shale with green jaspery seams. Barite blades occur with nodular accumulations of manganiferous calcite. Microscopically this layer is essentially a hematitic oölitic shale with the individual spherules measuring from 15 to 23 microns in diameter while larger aggregations of spherules measure from 0.253 mm. to 0.387 mm. in diameter. The spherules consisting of hematite and car-

bonate are found in a groundmass the character and composition of which is for the most part indeterminable. Occasional pyrite grains are found (Fig. 26, Slide 280).

219 A 10d, the upper subdivision, consists of 0.3 of a foot of nodular and oölitic dark gray shale with thin jaspery manganese carbonate laminations.

Subdivision **e** is a dark green nodular and oölitic shale, 0.8 of a foot in thickness and not very different from the layer **d** just described, and **f**—is a coarse nodular seam, 0.8 of a foot in thickness, in a dark green shale, comprising the uppermost portion of this bed.

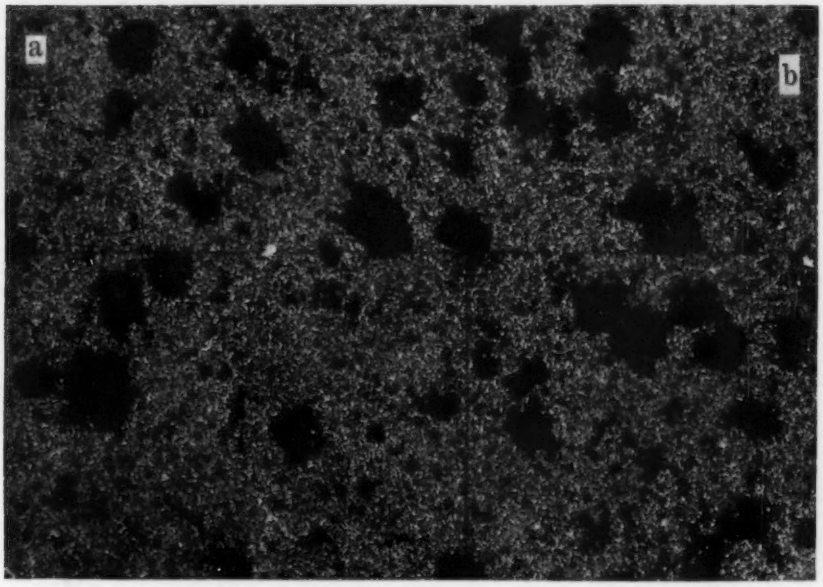


FIG. 26. Microphotograph of oölitic manganiferous shale from 219 A10c; slide 280; enlarged 22 diam. **a**, hematite spherules; **b**, shale with disseminated hematite.

219 A 11 is a heavy tough reddish band, 0.5 of a foot in thickness and lithologically very different from the immediately overlying and underlying beds. For the most part, the structure is both somewhat nodular and oölitic. The general fragmentary nature of the fossils and of certain nodular or pebbly forms leads one to think

that this layer consists in some degree of reworked material. The surface of this bed shows ripple marks. The predominant constituents which a macroscopic examination affords are calcite, barite, argillaceous material, limonite, manganese oxide, and pyrite. Outside of the nodular, oölitic, and fragmentary character of the layer,

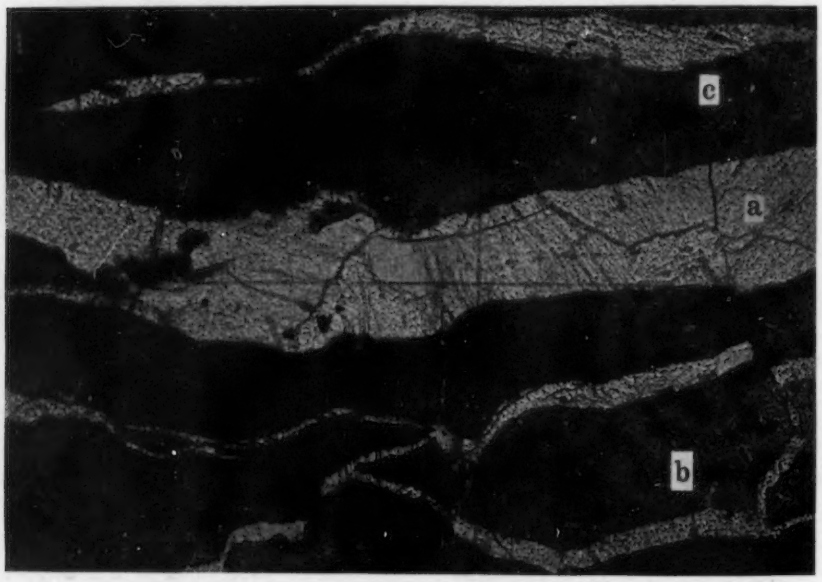


FIG. 27. Microphotograph of manganiferous red shale from 219 A11; slide 277; enlarged 22 diam. **a**, calcite vein; **b**, hematite spherule.

very little additional information concerning this peculiar rock could be gained microscopically (Fig. 27, Slide 277). The spherules are of two kinds, hematite and carbonate, and they average about 48 microns in diameter. Non-ferruginous portions of the slide show a groundmass of such fine-grained green material that very little could be made of it. *Hyolithes,* sponge spicules, and shell fragments partially or entirely replaced by calcite are a noticeable feature. Barite as scattered blades partially replaced by chlorite and pyrite, hematite as the chief constituent of the spherules, and carbonate are the most abundant of the determinable constituents of the slide (Fig. 28, Slide 278).

The chemical analysis of this rock is as follows:

Analysis *F*. *219 A 11.*		Analysis *F* 1. *Recalculation.*	
SiO_2	18.42	MnO	9.36
Fe_2O_3	6.33	$MnCO_3$	19.22
Al_2O_3	7.95	$CaCO_3$	18.61
MnO	21.44	$MgCO_3$	10.54
CaO	14.46	$Ca_3(PO_4)_2$	7.50
MgO	5.01	Fe_2O_3	6.22
P_2O_5	3.46	SiO_2	9.18
H_2O	2.58	$2H_2O \cdot Al_2O_3 \cdot 2SiO_2$	19.61
CO_2	21.20		100.24
	100.85		

This bed is essentially a manganiferous argillaceous dolomite with considerable percentages of barite, hematite, and phosphate. It would seem quite reasonable to suppose that the phosphate $Ca_3(PO_4)_2$ exists in the nodular portion as we have found to be the case in the nodules of 219 A 13 to be described later.

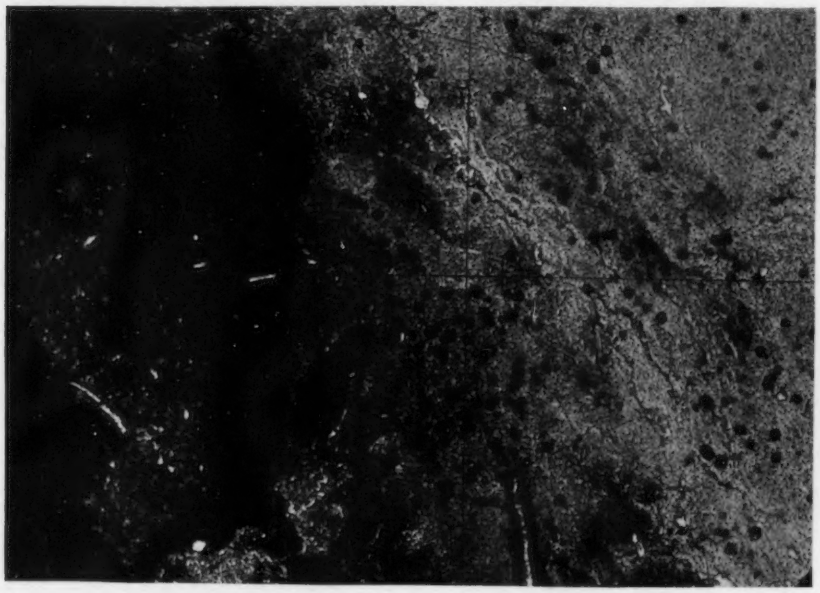


Fig. 28. Microphotograph of red manganiferous shale from 219 A11; slide 278; enlarged 22 diam.; showing hematite spherules in a groundmass of manganese carbonate.

219 A 12 is a fissile green shale measuring 1.4 feet in thickness with conspicuous black nodules which on weathering become white. Because of the similarity in form and color with those of 219 B 5, A 5, A 11, and those to be described from the bed immediately above this one, the suggestion is made here that these nodules also may be phosphatic.

219 A 13 is a phosphatic nodular manganiferous calcareous shale bed, 1 foot thick, with the nodules common in both bottom and top portions of the bed (Fig. 29). The nodules because of their white

FIG. 29. Photograph of a polished vertical section of a phosphatic nodular shale seam, 219 A13; natural size. **a**, phosphatic nodule; **b**, shale with trilobite fragments.

weathering and subspherical to elongated form resemble those of 219 A 12, A 11, A 5, and B 5. In chemical composition the nodules of this bed resemble those from the Cambrian of southern New Bruns-

wick described by W. D. Matthew (15). The chemical analyses of the Manuels brook and the New Brunswick phosphate nodules are as follows:

ANALYSIS *H.*

Manuels Brook, N. F.		*Hanford Brook, N. B.*	
SiO_2	25.20	SiO_2	24.74
Al_2O_3	7.67	Al_2O_3	11.85
Fe_2O_3	10.13	Fe_2O_3	11.44
CaO	23.50	CaO	22.35
MgO	4.78	KO	0.59
P_2O_5	17.68	MgO	2.29
H_2O	2.71	NaO	1.41
CO_2	2.23	P_2O_5	14.99
	93.90	H_2O	3.43
			3.44
		CO_2	3.53
			100.06

The similarity between the percentages of SiO_2, Fe_2O_3, CaO and P_2O_5 of the two analyses is at once very noticeable and at the same time very suggestive. It is hoped that at some future time, work of a correlative nature may be taken up in connection with these interesting and genetically problematical nodules. Among the macroscopically observable minerals in the fresh and altered rock are pyrite, hematite, limonite, wad or psilomelane, and vivianite in an argillaceous dolomitic groundmass. *Hyolithes* fragments are in abundance.

As no apparent manganese was observable in the considerable thickness of overlying green shales, 219 A 13 was considered to be the top of the manganese zone at Manuels Brook. According to Prof. van Ingen the *Paradoxides* fauna begins in these shales which immediately overlie the manganese zone.

TOPSAIL.—The manganese at Topsail some 4 miles east of Manuels (see Figs. 1 and 30) occurs interbedded in steep northerly dipping (50° to 78°) lower Cambrian strata consisting of shales, limestones and sandstones. The manganese is found in several beds of which only one measuring 1.4 feet in thickness seems to be of sufficient importance to have warranted prospecting, as shown by

some open cutting. This is a carbonate-oxide ore of manganese of brown color and vitreous luster.

Not only does the character and structure of the manganese at Topsail differ from that of Manuels but the section shows some

FIG. 30. Photograph of the open cut with the manganese prospect tunnel at Topsail; Loc. 219 E.

lithological variations. Moreover the rocks of the section are very much disturbed with the rapid changes in the dip of the beds. The structural changes in these beds are no doubt due to the great fault, the plane of which passes about 300 feet east from the manganese zone with a strike of N. 13 E. and a vertical dip. The fault plane lies between the Huronian and the lower Cambrian, and the beds immediately adjacent are considerably disturbed and so to a lesser extent are those farther away.

That a better idea may be obtained as to the relationship of the manganese, the following general and local stratigraphic sections with descriptions are given. The generalized section as worked out by Prof. van Ingen and Mr. A. O. Hayes during the summer of 1912 is as follows:

Loc. Number.			
210 E 10	Brown shales with manganese at base	Open cut	
9	Brown shales with limestone at base.		
8	Heavy limestone.		
		Ft.	
7	Shaly limestone	6.0	
6	Brown sandstone with limestone nodules	3.0	
5	Fine and coarse sandstone with small limestone nodules	6.0	
4	Much sheared brown shale with limestone nodules and manganese at base	4.0	
3	Mouth of tunnel and rotten zone	15.0	
2	Coarse sandstone	6.0	
1	Shear zone	0.3	to 0.5
0	Pre-Cambrian	25.0	

It is quite apparent from a study of the above section that the lower Cambrian at Topsail is in many respects similar to that of Manuels. The absence of a basal conglomerate and the presence of sandstone are the most striking features of the associated beds. During the summer of 1913 a more detailed study of the manganese zone of 210 E 10 of the generalized section was made and the following subdivisions were made:

Loc. Number.		Ft.
219 E 7	Green shale, badly broken.	
6	Banded, concentric and nodular shale	1.0
5	Green shale, badly sheared	0.5
4	Manganese oxide-carbonate ore	1.4
3	Broken nodular green shale with manganese stain	0.7
2	Calcareous manganiferous shale	0.3
1	Hard nodular olive green shale, badly weathered and sheared, with manganese stain.	

Of this series two beds, 219 E 4 and 6, are worthy of more detailed description.

219 E 4 is an oxide-carbonate ore of manganese of 1.4 ft. in thickness. It is irregularly banded and nodular, of chocolate-brown color, somewhat vitreous in appearance and argillaceous, with a hardness of 5 to 6 and specific gravity of 3.26. Disseminated

through the ore are irregular small areas of a pink carbonate resembling rhodochrosite in physical characteristics, and barite. The ore is incrusted with psilomelane as an oxidation product. Microscopic examination brings out a coarsely banded and nodular structure with a groundmass of indeterminate material which is for the most part homogeneous to all appearances and of brown color.

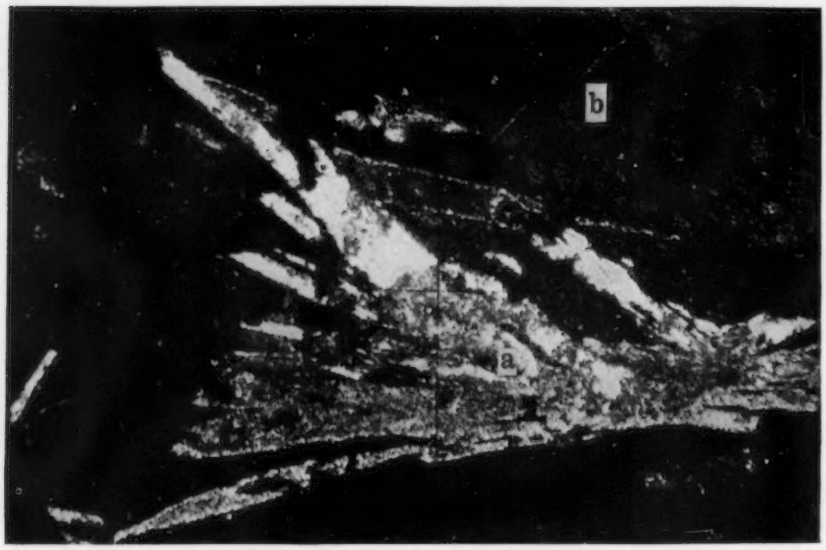


FIG. 31. Microphotograph of barite sheaf in manganese oxide-carbonate ore from 219 E4; slide 269; enlarged 22 diam. **a**, barite sheaf; **b**, manganese oxide-carbonate ore.

The color of this ore is due to the brown and black oxides of manganese and iron. Conspicuous among the anisotropic minerals are barite which occurs as blades or bundles of blades generally replaced by chlorite, and calcite, all very much discolored by the manganiferous and ferruginous oxides. Minute veins of discolored calcite are present (see Fig. 31, Slide 269).

The chemical analysis of the ore and its recalculation are as follows:

Analysis *I.*		Analysis *I* 1.	
219 E 4		*Recalculation.*	
SiO_2	18.04	MnO_2	34.25
Fe_2O_3	4.82	$MnCO_3$	11.27
Al_2O_3	6.58	$CaCO_3$	4.00
MnO	41.26	$MgCO_3$	4.97
CaO	2.24	SiO_2	10.32
MgO	2.39	$BaSO_4$	5.40
$BaSO_4$	5.40	Fe_2O_3	4.82
CO_2	8.34	$2H_2O \cdot Al_2O_3 \cdot 2SiO_2$	16.30
H_2O	7.98	H_2O	5.41
	97.05		96.74

This is essentially a hydrous oxide of manganese with considerable amounts of argillaceous material, rhodochrosite, silicious matter, dolomite, barite and hematite in descending order of abundance.

219 E 6, not a manganese ore bed, though manganiferous, is of interest mineralogically and petrographically. In structure it is concretionary and banded, nodular and microscopically oölitic. It is essentially a calcareous, ferruginous and manganiferous nodular and banded shale (see Fig. 32). Under the microscope the greater part of the groundmass, isotropic under crossed nicols, is of indeterminable composition simulating phosphatic material. Of the anisotropic minerals, calcite is most frequent and occurs with other carbonate material in bands which show an oölitic structure. The individual spherules, subspherical to elliptical in form show either concentric or radiated structure, the latter showing an interference cross with crossed nicols (Fig. 33, Slide 272). Calcite frequently has the curved twinning planes indicative of strain. Barite occurs in narrow veins or bands, as disseminated blades, or as sheath-like blades or aggregations, usually being replaced to a greater or less extent by chlorite and in a few instances by pyrite (Fig. 34, Slide 272). The spherules consist of hematitic pigment, carbonate and chlorite. Because of the frequent association of chlorite with barite one is led to suspect that possibly the chlorite spherules were originally of barite which has since been replaced by the chlorite. Other spherules made up in great part of hematite, sometimes show-

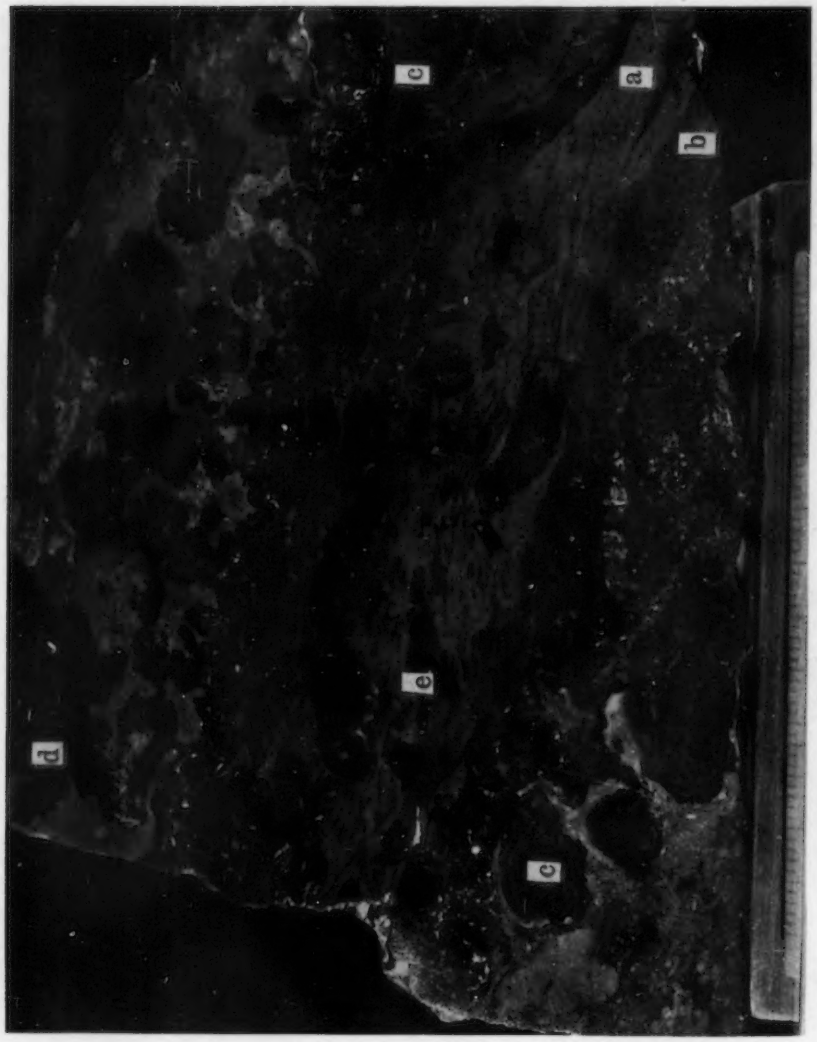


FIG. 32. Photograph of polished vertical section of banded and nodular shale from 219 E6; natural size. **a**, green shale; **b**, hematite nodule in hematite band; **c**, ferromanganese concretion; **d**, phosphatic nodule.

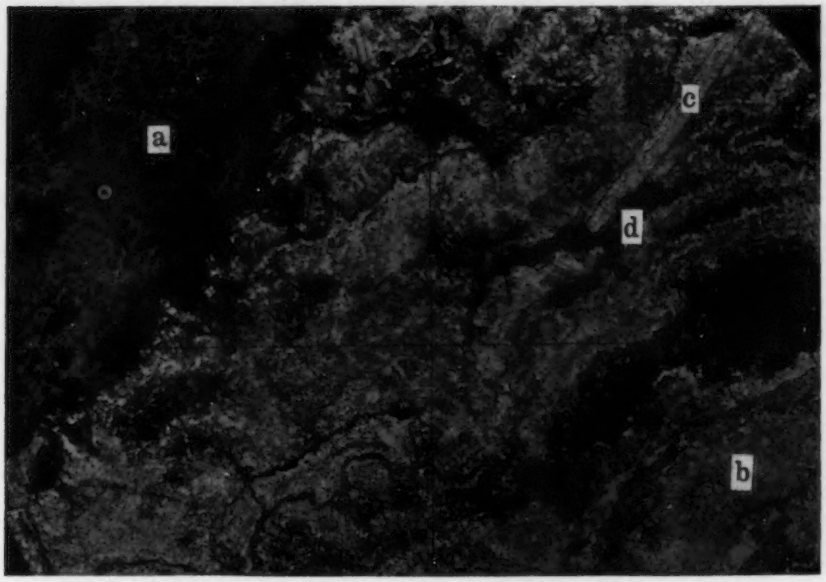


FIG. 33. Microphotograph of banded and nodular shale from 219 E6; slide 272; enlarged 38 diam. a, oölitic hematite shale; b, carbonate calcite band; c, barite; d, pyrite.

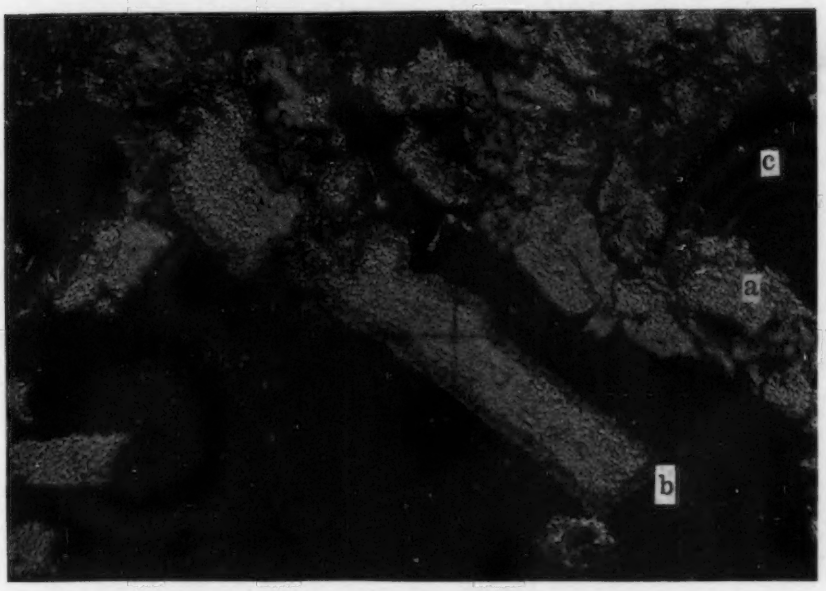


FIG. 34. Microphotograph of barite with chlorite replacement from 219 E6; slide 272; enlarged 22 diam. a, barite; b, chlorite replacing barite; c, phosphatic? material.

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ing carbonate centers, are found most frequently in the jaspery bands. The spherules vary in size from 12 to 120 microns but have average diameter of about 94 microns.

The chemical analysis of this bed, with its recalculation, is as follows:

219 E 6.		*Recalculation.*	
SiO_2	18.24	$MnCO_3$	16.79
Fe_2O_3	10.01	$CaCO_3$	20.91
Al_2O_3	14.52	$MgCO_3$	10.57
MnO	10.42	$FeCO_3$	4.52
CaO	13.74	Fe_2O_3	5.49
MgO	4.94	$Ca_3(PO_4)_2$	3.75
P_2O_5	1.71	SiO_2	1.20
CO_2	24.01	$2H_2O \cdot Al_2O_3 \cdot 2SiO_2$	36.38
H_2O	2.07		99.61
	99.66		

From the above analysis, this rock is essentially a dolomitic manganiferous ferruginous shale with considerable amounts of $Ca_3(PO_4)_2$. Among the microscopically observable minerals in the above recalculation are calcite, hematite, quartz. The nodular portions, usually isotropic and of exceedingly fine grain, are probably

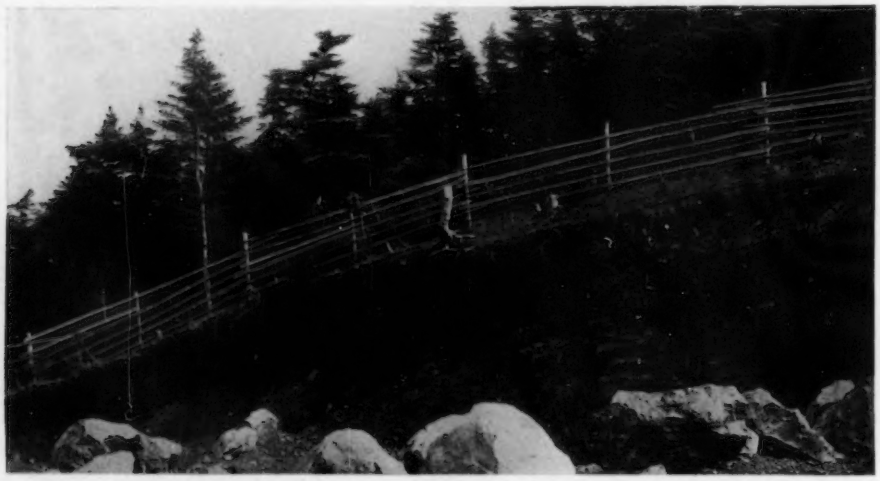

FIG. 35. Photograph of manganese prospect along the Kelligrews highway just south of Long Pond; Loc. 219 F.

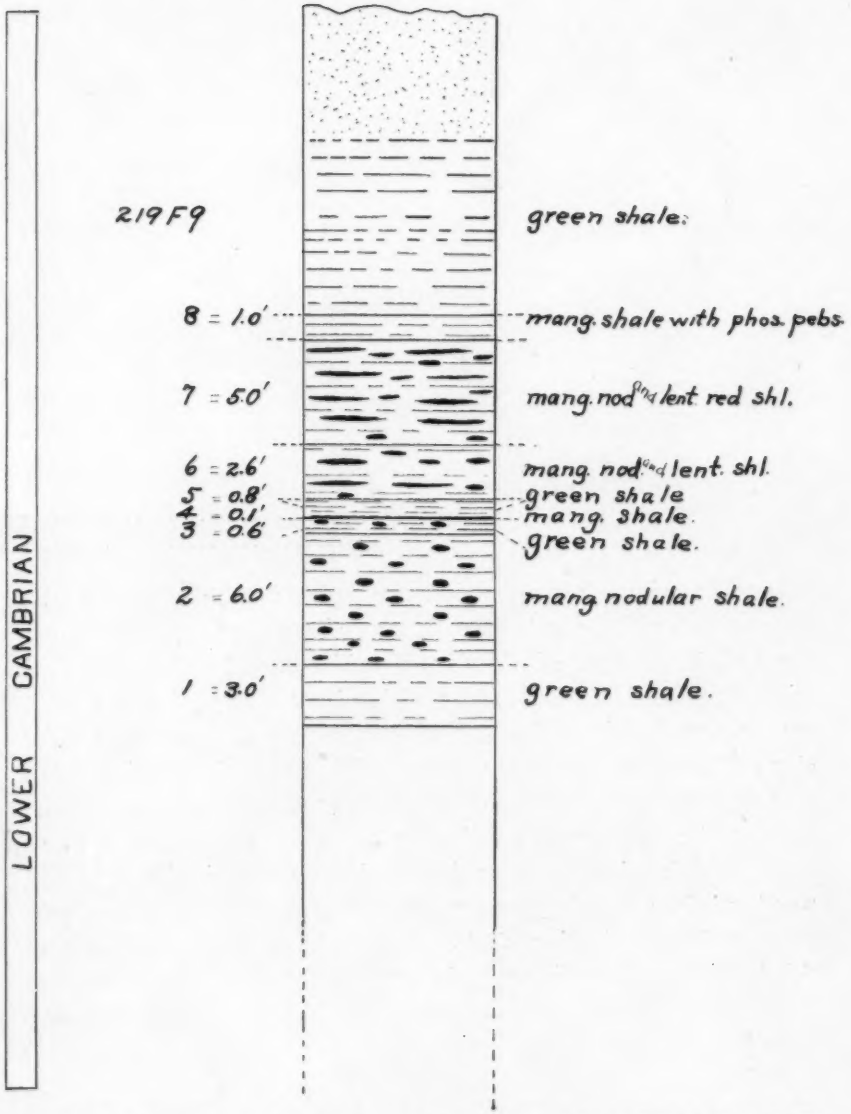

FIG. 36. Columnar section of the manganese zone at Long Pond; Loc. 219 F.

in great part shaly in composition. The nodules of this band suggest a very possible analogy to those of 219 A 5, 11, 12, 13, and B 5. In as much as this bed is somewhat phosphatic, the phosphate in all likelihood is associated with the nodules, as is the case with the nodules of 219 A 13 of Manuels. This bed is structurally and mineralogically quite similar to the phosphatic beds of Manuels.

LONG POND SECTION.—About 2½ miles southwest of Manuels and west of the railroad and wagon road (see Fig. 35), manganese occurs, in a low cliff, as nodular and banded layers interbedded with shales. Though the manganiferous beds at this locality are considerably more oxidized than those at Manuels, the occurrence as a whole is similar and it is necessary to present the section with only brief macroscopical descriptions of the important beds (Fig. 36).

Loc. Number.		Ft
219 F 10	Glacial mantle.	
9	Manganiferous green shale.	
8	Phosphatic nodular manganese shale	1.0
7	Manganiferous nodular and lenticular green shale	5.0
6	Banded nodular ore	2.6
5	Fissile green shale	0.8
4	Manganiferous banded ore	0.1
3	Massive nodular green shale	0.6
2	Nodular shale	6.0
1	Heavy green olive shale	3.0

219 F 2 of the above section corresponds quite closely to the lower nodular bed, 219 A 4a, of Manuels (see page 392), chiefly because of the presence of abundant discoidal-shaped nodules identical with those at Manuels. The nodules have altered for the most part to a wad and clay, some having secondary manganese or white clay centers and clay border zones and others with limonitic green clay centers with secondary manganiferous clay border zones. The weathered nodules are very abundant.

219 F 6 is a heavy manganiferous bed composed of several ½″ to 3″ red, brown and green manganiferous seams separated by thin nodular shale laminations that are now red. It is quite evident that this bed is a continuation of either 219 A 7 or 10 of Manuels. The interior of some of the weathered nodules is a red and green residual clay. The manganiferous seams weather reddish and greenish.

219 F 7 is probably a continuation of 219 A 8 and 9 of Manuels inasmuch as this bed is nodular and has many lenticular and continuous jaspery seams of 0.1 inch to 1 inch in thickness alternating with ½ inch to 1 inch seams of reddish manganiferous shale.

219 F 8 from its similarity to 219 A 13 of Manuels may be described as a phosphatic nodular manganiferous shale with the manganese in evidence as some hydrous oxide.

CHAPEL COVE SECTION.—The manganese at Chapel Cove, of inconsiderable amount, occurs in a very much faulted series of lower Cambrian limestones and shales as alteration products on many of the structural planes. If it were not for certain lithological analogies with the deposits just described it would hardly seem necessary to give any detailed description of this deposit because of the small quantity of manganese present (see Figs. 1 and 37).

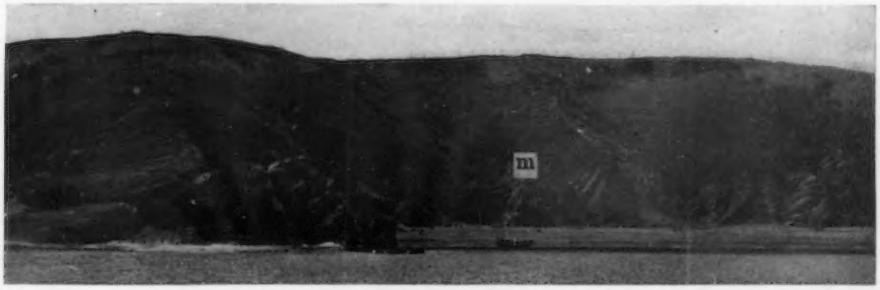

FIG. 37. Photograph of the section along the shore at Chapel Cove near Holyrood, Loc. 213 C; showing the managenese zone at (**m**).

The generalized section as worked out by Prof. G. van Ingen and Mr. A. O. Hayes during the summer of 1912 is as follows:

Loc. Number.			Ft.
213 C	4	c Olive green shale.	
		b Alternate pink layers with small black pebbles, manganese layer	3.6
		a Olive green shale, sheared near fault.	
	C 3	Nodular limestone and shale	24.0
	7	Argillaceous red limestone and alternating shales	25.0
	6	Red shaly limestone	18.0
	5	Red shale	8.0
	D 7	Heavy red limestone	10.0
	6	Red shales with limestone.	
	5	Red and green limestone.	
	4	Green limestone.	

E 2 Gray limestone.
1 Conglomerate with pebbles of syenite, black chert and limestone.
0 Syenite.
C 2 Agglomerate.
1 Ribbon slates. Conception slates (Huronian).

The section represents the stratigraphic sequence and the locality numbers indicate the position of the layers. Quoting Prof. van Ingen in regard to this most interesting locality:

"It appears to me that we have here the remnant of a squeezed syncline, the northern margin of which has been shoved far northwardly onto the underlying agglomerate and ribbon slates."

213 C 4b was studied more in detail by the writer during the summer of 1913 in the hope that some more definite knowledge might be gained on the occurrence of the manganese at this point, but without very much satisfaction. The subdivided manganese bed is as follows:

Loc. Number.
213 L 4 c Finely banded nodular bed.
b Fractured and slickensided green shale.
213 L 4 a Black nodular calcareous green shale with manganese staining.
L 3 Nodular ferruginous calcareous green shale with manganese stains.
2 Fractured and fissile shale.
1 Manganiferous calcareous green shale with hematite and pyrite.

In as much as the manganese was not visible to any great extent in its primary form throughout this small series of 3 to 4 feet no analysis was thought necessary. Two of the above beds, 213 L 3 and 213 L 4 are worthy of macroscopical and microscopical descriptions because of marked lithological resemblance to certain of the rocks at Manuels.

213 L 3 is a nodular shale with conspicuous calcareous ferruginous and manganiferous aggregations and jet black pebbles or nodular forms. All structural and divisional planes of this bed are conspicuously stained with some secondary oxide of manganese, probably a hydrated oxide such as psilomelane. Microscopical examination of this shale brings out the fact that the structure is nodular and oölitic and that the rock is a ferruginous chloritic shale.

The groundmass consists of chlorite and, for the most part, of an indeterminable material. Calcite occurs as an alteration product or as a constituent of the hematitic spherules. Quartz is found composing infrequent aggregates and as vein-filling material. The opaque minerals other than hematite are manganese as psilomelane or some other secondary derivative, pyrite as disseminations, and

FIG. 38. Photograph of manganese prospect on Brigus South Head; Loc. 212 A12a. **a**, oxidized manganese beds; **b**, green shale.

limonite as a yellow staining. The spherules are for the most part hematite in composition but carbonate is a very common constituent. The diameters of the spherules range from 21 to 159 microns but average around 44 and 77 microns. The ferruginous centers of some of the spherules measure 0.8 of a micron.

Certain discoidal nodules in **213 L 4c** resemble those of 219 A 4 at Manuels though they are very much less abundant.

213 L 4a is nodular and the texture exceedingly fine-grained and locally crystalline. The greater portion of the thin section is probably composed of shale material and the remainder is taken up in great part by calcite and carbonate disseminations, as replacement material of hyolithes shells, or as mineral aggregates. Barite occurs

FIG. 39. View of Brigus South Head looking across the mouth of the harbor in a northerly direction and showing the position of the manganese zone (a–a).

as infrequent disseminations and individual platy crystals and probably once formed the *Hyolithes*-like rods now replaced by chlorite and a carbonate. Pyrite and hematite are found. The nodules of this bed, subspherical in shape, show under the microscope a compact

FIG. 40. View of the manganese beds (a) dipping into the sea on the east side of Brigus South Head.

structure and an almost impalpable fineness of grain. Under crossed nicols an occasional angular fragment of quartz is found but the groundmass as a whole appears to be isotropic. It is possible that these pebbles are analogous to the phosphate pebbles of Manuels, Topsail, and Long Pond.

Brigus Section.—At Brigus South Head on the west shore of Conception Bay (see Figs. 1, 38, 39, 40, and 41) manganese is found to a great extent in the oxidized state in several beds at the water's edge in the shales of lower Cambrian age which make up the sharp hog back ridge overlooking the "Needles." Because of the inac-

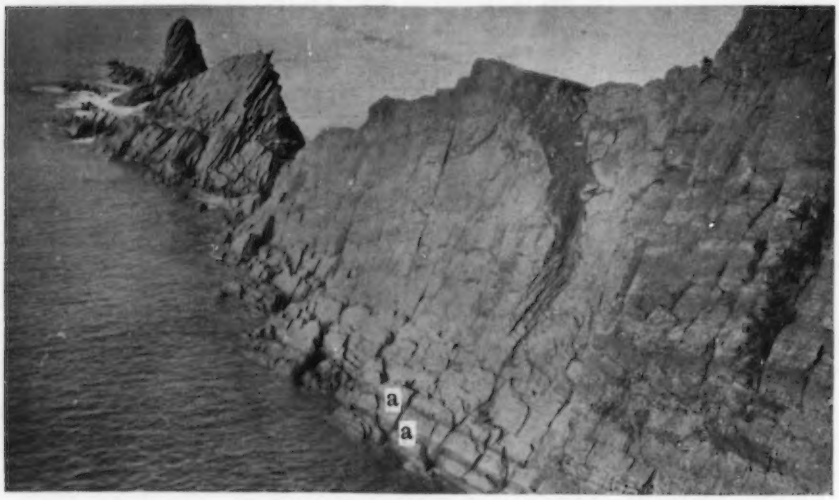

Fig. 41. View of the "Needles" at the extremity of Brigus South Head, showing the manganese zone (a–a).

cessibility of that portion of the ridge where the manganese was best preserved, detailed measurement of the section was not possible. Prof. van Ingen and Mr. A. O. Hayes in 1912 found that the best manganese measured about 4.5 feet thick in a zone of 15 feet. Specimens collected from more accessible portions were all practically altered to psilomelane but there is one which shows the original jaspery carbonate quite similar to the types described in connection with the Manuels occurrence. Several old prospect pits on the more accessible parts of this ridge were examined by the writer, but the manganese was found to be in its secondary state and the interbedded shales in a very much disturbed condition. The strike of the strata of this locality is N. 10 E. and the dip 47 E.

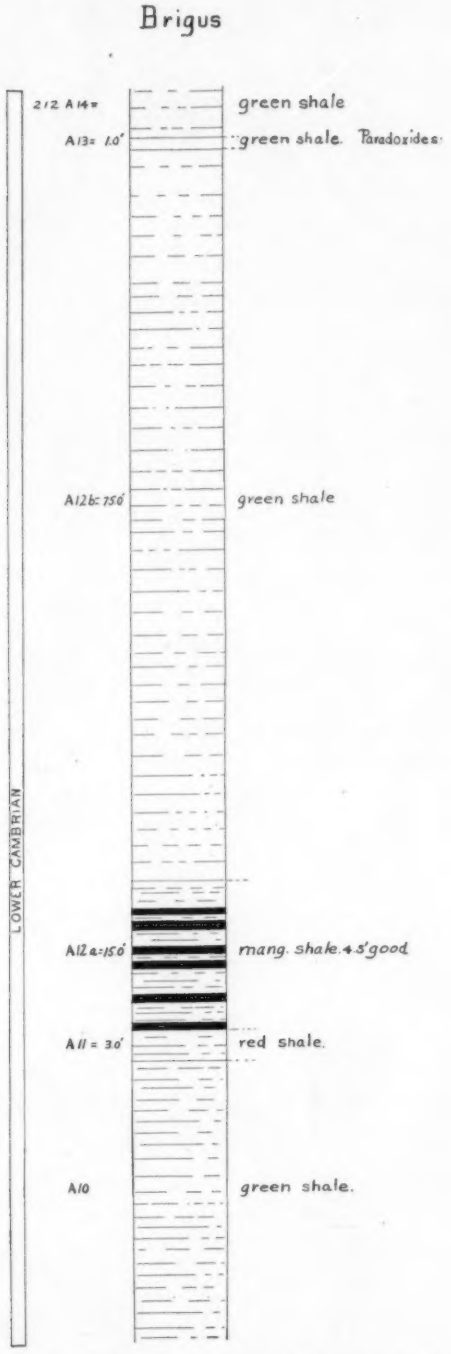

FIG. 42. Columnar section of a portion of the lower Cambrian at Brigus South Head, from measurements made by Gilbert van Ingen and A. O. Hayes, 1912.

The following section as prepared by Prof. van Ingen and Mr. A. O. Hayes from their study of the region in 1912 shows the stratigraphic relations of the manganese deposits at this point (Figs. 39 and 42).

Loc. Number.		Ft.
212 A 14	Green shales, end of needles	50.0
13	*Paradoxides* zone, green shales	1.0
212 A 12 b	Green shales	75.0
12 a	Manganese zone (4.5 ft. best)	15.0
11	Red shales, thin band	3.0
10	Green shale	60.0
9	Red shale	210.0
8	Red shaly limestone	11.6
7	Red shale	28.0
6	Limestone, heavy white at base, nodular and red above. *Holmia bröggeri* and other trilobites	30.0
5	Red shale	5.0
4	Limestone, very shaly	12.0
3	Red shale	32.0
2	Limestone with Cryptozoon	30.0
1	Red shale with local sandstone and conglomerate	50.0
	Unconformity.	
0	Pre-Cambrian shale and ash beds.	

The striking feature of this section is the position of the manganese zone in relation to the *Paradoxides* bed which is exactly the relation established at Manuels and undoubtedly at the other localities described.

Smith Sound Section, Trinity Bay.—The manganese zone on Trinity bay occurs at Smith Point (Fig. 1) as two massive beds associated with red and green nodular shales and limestones of lower Cambrian age. The accompanying map (Fig. 43), prepared from a transit survey of the shore line by Prof. van. Ingen during the summer of 1913, shows the structural and stratigraphic relations of the two manganese beds, 230 D 20 and D 27. The general strike of these beds is north and the dip, 20 west.

230 D 27, the important manganese bed of this section (Figs. 44, 45), measures some 38 inches in thickness, and is faulted with a downthrow of 15 feet on the west side. It is the thicker of the two manganese beds, and has been found by analysis to be essentially a

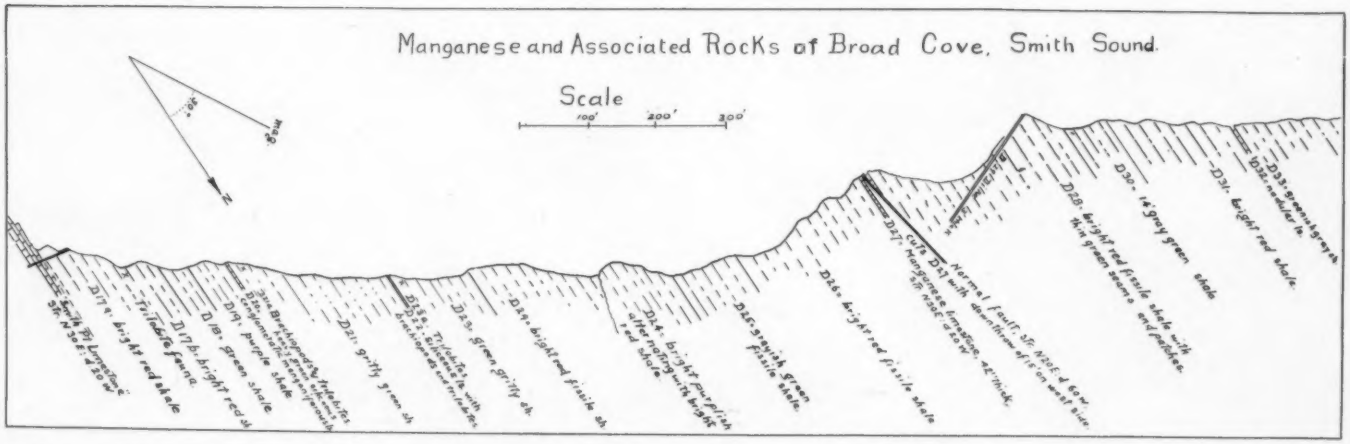
Manganese and Associated Rocks of Broad Cove, Smith Sound.
Scale
100'
200'
300'
N
Normal fault, throw about 40'
D33. greenish-grey to dull red nodular ls
D32. nodular ls
D31. bright red shale
D30. ls grey green shale
D29. bright red fissile shale with thin green seams and nodules
D28. bright red fissile shale
D27. cuts D28 with downthrow of 15' on west side
D26. bright red fissile shale
D25. greyish green fissile shale
D24. bright purplish silver mottled grey to bright red shale
D23. bright red fissile sh
D22. green gritty sh
D21. gritty green sh
D20. Trilobites with brachiopods and fragments
D19. purple shale
D18. green shale
D17b. bright red sh
D17a. bright red shale

FIG. 43. Map of the outcrops of the protolenus and manganese zones exposed on the shore of Broad Cove, near Smith Point, Smith Sound, traced from field map based on stadia transit surveys by Gilbert van Ingen, 1913.

FIG. 44. Columnar section of a portion of the lower Cambrian at Broad Cove, near Smith Point, Smith Sound, Trinity Bay, Newfoundland, showing the manganese zone, 230 D26 to 28.

manganiferous dolomitic ferruginous shale. The bed is somewhat massive and nodular though the nodules are very irregular as compared with those at Manuels and other localities; irregular crystalline areas form the nodular portions while the matrix is made up of more argillaceous matter. Thin sections taken from the bottom and central portions of the bed were examined microscopically.

FIG. 45. Exposure of manganese ore, 230 D27, on the Broad Cove shore, near Smith Point, Smith Sound. This is a nodular ferro-manganese carbonate-oxide bed.

230 D 27aa is a reddish nodular and oölitic shale, with hematitic carbonate making up the greater portion of the determinable minerals; aggregations of a fine-grained dark material suggest phosphatic nodules so common in the Manuels occurrence. Irregular grains of quartz and aggregations of chlorite are found. Sections of trilobites and other organic forms containing carbonate material abound. Some hydrous manganic dioxide occurs (Fig. 47, Slide 299). Sections from the middle portions of the bed, **230 D 27e,** show a somewhat massive, nodular or oölitic reddish rock. Hematite is found as a pigment and to a lesser extent as lustrous opaque grains to which the color of the rock is due. A manganic oxide occurs as irregular and infrequent grains. Carbonate occurs as vein filling, as irregular areas, or as replacements of sponge spicules

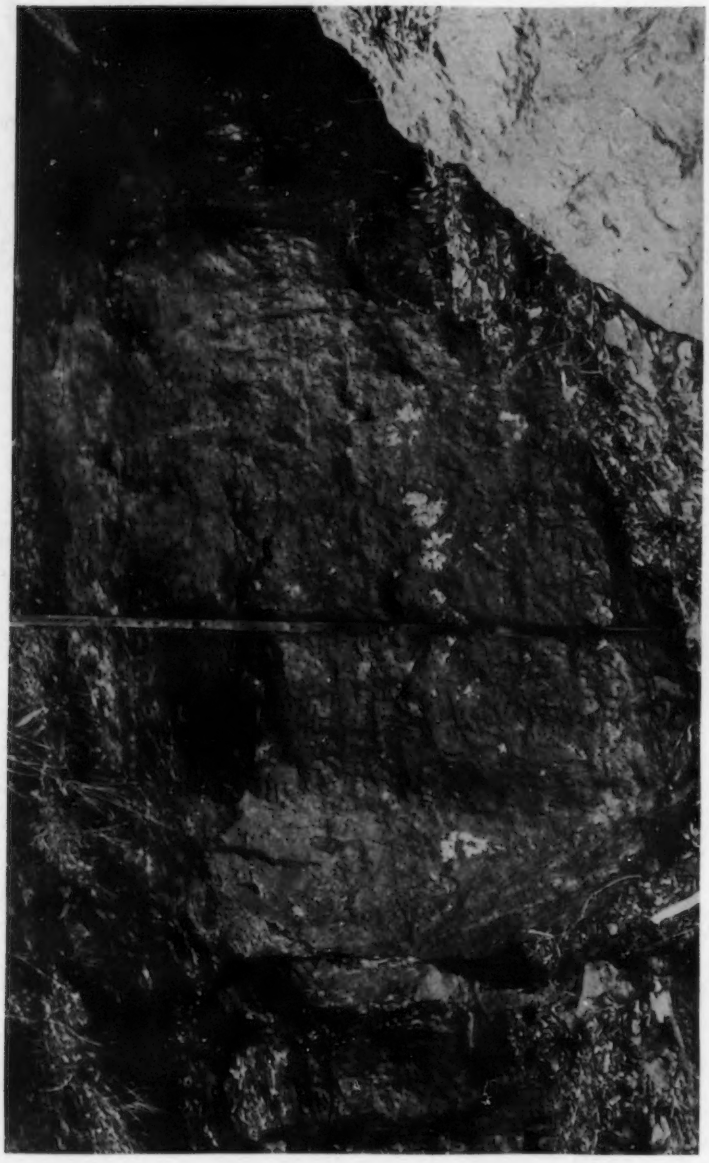

FIG. 46. Nearer view of the ferro-manganese ore bed, 230 D27 on the Broad Cove shore.

and other organic bodies. Barite is found infrequently, sometimes with chlorite fringing it. Chlorite may be found replacing trilobite fragments.

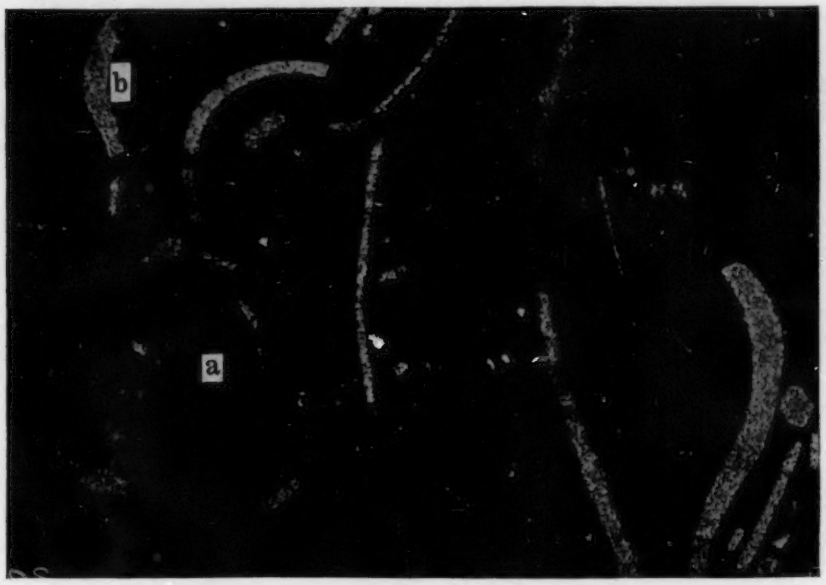

FIG. 47. Microphotograph of fossiliferous manganese ore, 230 D27; slide 299; from Broad Cove; enlarged 22 diam. **a**, manganese carbonate-oxide ore; **b**, fragment of trilobite test.

The following analysis and recalculation represent the chemical composition of an average sample of the bed and will corroborate some of the petrographic observations:

ANALYSIS *K*.

230 D 27.

SiO_2	15.14
Fe_2O_3	9.22
Al_2O_3	12.04
MnO	25.63
CaO	10.04
MgO	3.72
P_2O_5	1.26
H_2O	2.73
CO_2	21.05
	100.83

ANALYSIS *K* 1.

Recalculation.

$MnCO_3$	26.91
MnO_2	9.00
$CaCO_3$	15.21
$MgCO_3$	7.75
Fe_2O_3	9.22
$Ca_3(PO_4)_2$	2.50
SiO_2	.84
$2H_2O \cdot Al_2O_3 \cdot 2SiO_2$	30.06
	101.49

The manganese according to the recalculation of the analysis is essentially in the form of a rhodochrosite and whatever manganese there is in excess probably exists as a peroxide. It is quite possible that $Ca_3(PO_4)_2$ exists in the irregular black fine-grained areas, though nothing definite can be said in confirmation of it at this time.

SECTION OF THE LOWER CAMBRIAN FROM THE BASE OF THE LOWER PARADOXIDES ZONE DOWN TO THE TOP OF THE SMITH POINT LIMESTONE, TRINITY BAY (Fig. 47).

Loc. Number.		Ft.
230 D 32	Thin seams of nodular limestone in red shale	4.0
31	Bright red shale	46.0
30	Gray green shale	14.0
29	Dike	3.0
28	Bright red fissile shale with thin green seams and patches	97.0
27	Manganese limestone (manganiferous dolomitic shale)	3.5
26	Bright red fissile shale	78.0
25	Grayish green fissile shale	28.0
24	Bright purplish shale alternating with bright red shale	97.0
23	Green gritty shale	33.0
22	Gray band of fine grain silicious limestone full of pyrites and same brachiopods and trilobites	0.5
21	Gritty green shale, brachiopods and trilobites	62.0
20	Heavy green silicious conglomeratic manganiferous limestone	2.5
19	Purple shale	10.0
18	Green shale	10.0
17	Red shale	47.0
	b—Contains trilobite fauna ..... 13.0 ft.	
	a—Red shale 19.0	
	Interval covered 15.0	
16	Smith Point Limestone.	
	Total	535.5

V. OTHER MANGANESE DEPOSITS OF SOMEWHAT SIMILAR CHARACTER.

Sedimentary deposits of manganese are not of uncommon occurrence but it is rare that we find such deposits still in their unaltered condition as they were originally formed. There are however a few deposits elsewhere which in many respects resemble the Conception Bay and Smith Sound occurrences.

NEWFOUNDLAND, PLACENTIA BAY. In Placentia Bay, New-

foundland, manganese has been described by Murray and Howley as a massive carbonate bed interbedded with slates of "Silurian" age. Dr. T. Sterry Hunt (12: 204 and 205) described this mineral as

"compact and impalpable in texture, brittle, with a conchoidal fracture and a feeble waxy luster; slightly translucent on the thin edges; color fawn to pale chestnut-brown; streak white, hardness 4.0; density 3.25. The specimen shows faint lines which seem to be those of deposition and give to the mass the aspect of a sinter. It is encrusted and penetrated in parts with black crystalline oxide of manganese. The presence of oxide of manganese in this mineral is probably due to its partial decomposition." Analysis of this mineral by Dr. Hunt is as follows:

$MnCO_3$	84.6
SiO_2	14.40
Fe, CaO and MgO	traces

"This deposit is of interest on account of the existence of the metal in the form of a bedded carbonate. It probably represents the former condition of many of the oxide ores of manganese elsewhere in the stratified rocks, but they have since been converted to their more stable form."

It is quite evident from the above description of the Placentia Bay manganese that we have in all probability a deposit similar in mineralogic character and stratigraphic position to those in Conception Bay. No published stratigraphical or palæontological work has appeared on the Placentia Bay occurrences. In that portion of this paper relating to the stratigraphy of the manganese deposits it will be readily seen that the basin into which the manganiferous muds were deposited to form the present manganese beds of the lower Cambrian probably extended to or covered Placentia Bay or that portion of Placentia Bay where we now find Cambrian rocks. There is no doubt that the "Silurian rocks" referred to above by Howley and Murray are the lower Cambrian.

WALES.—Sedimentary manganese deposits have been described as occurring in the Cambrian rocks of Merionethshire, North Wales by Mr. Edward Halse (9: 156) in an article entitled, "The Occurrence of Manganese Ore in the Cambrian Rocks of Merionethshire." He says:

"in the Harlech mine, the bed of ore is a little over a foot thick, consisting of grit of medium grain, overlaid by a thin band of quartzite, probably meta-

morphosed grit. The roof proper consist of about 2 feet of very hard, schistose rocks, termed 'blue stone' by the miners. Specimens of ore taken from the mine are seen to be formed of uniform layers, having gray yellowish, white, greenish and chocolate-brown layers."

A reference by J. A. Phillips and Henry Louis (21:296) to the same occurrence is as follows:

"Beds of carbonate of manganese with some silicate, the outcrops of which have been to some extent changed into black oxide, occur intercalated between sandstones, grits and conglomerates of the Cambrian formation, and have been mined to some extent; the beds vary from one to two feet in thickness, and yield ore, averaging about twenty-seven per cent. of metal, which is used in spiegel making. These deposits are evidently symphytic and belong to group b of that class."

Phillips and Louis believe that these deposits were formed syngenetically but from precipitates in aqueous solutions. This deposit suggests very striking similarities to the Manuels occurrence not only mineralogically and genetically but also from the standpoint of stratigraphy.

ARKANSAS.—The Cason tract of the Batesville region, Arkansas, presents certain petrological analogies to the Newfoundland occurrences. Dr. Penrose (20: 219) describes the ore as occurring

"in lenticular layers, varying from an eighth of an inch to three inches in thickness, and interstratified with an indurated red clay of a slaty structure. Generally, however, the ore occurs in the shape of flat, lenticular concretions, from a quarter of an inch to one inch in diameter, locally known as 'button ore.' They have a concentric structure, are dull black on the outside and bright on the inside and are imbedded in a red or brown, fine-grained and more or less calcareous sandstone."

Analyses of the ore run as follows:

Mn	34.64	50.41
Fe	4.88	7.56
SiO_2	25.65	12.67
P_2O_5	0.58	0.06
Al_2O_3	3.79	1.37
CaO	5.13	2.09

Similar conditions to those postulated by Penrose for the accumulation of the manganese in the Arkansas region seem to me to be applicable to the Newfoundland deposits.

In writing of the circulation of the manganiferous solutions and the conditions under which they might be precipitated in the coastal shoals or lagoons, Penrose says (20: 590, 591):

"This gradual local accumulation of land and marine sediments would eventually cause shoals and possibly coastal lagoons and swamps, into which the waters from Archæan rocks of the Missouri Archipelago would drain."

"Here the solutions exposed in a stationary condition to the oxidizing and evaporating action of the atmosphere, would deposit their metalliferous contents as carbonate or possibly oxide of manganese. In some places considerable bodies of ore might be formed in one spot, in others the manganese would be dessiminated through the mechanical sediments being laid down at the same time. A secondary chemical action might cause the segregation of the disseminated manganese and the formation of concretions of carbonate of manganese, which would be later oxidized in forms such as are characteristically shown at the Cason mine, near Batesville, and elsewhere in the region. In other places the manganese might remain in a finely disseminated state, causing the common occurrence now seen throughout the region of an earthy manganiferous limestone containing from 3 to 15 per cent. of manganese."

SAXONY.—The writer was led to analyze certain of the manganese minerals from Schebenholz near Elbingerode in the Harz, which were purchased from Krantz, because of certain physical resemblances to the Newfoundland specimens. One specimen labelled "Allagite with Dialogite, etc." consists of three different materials; the first is greenish and gave the following analysis:

SiO_2	39.10	$MnSiO_3$	33.98
Fe_2O_3	1.87	$MnCO_3$	15.05
Al_2O_3	10.79	$MgCO_3$	12.64
MnO	27.69	$CaCO_3$	1.70
CaO	1.00	SiO_2	10.97
MgO	6.08	Fe_2O_3	1.75
H_2O	1.13	$2H_2O \cdot Al_2O_3 \cdot 2SiO_2$	23.76
CO_2	13.13		99.85
	100.79		

Unfortunately the early descriptions of this substance were not quoted very fully by later writers, but one of the imported specimens which was similar to the one analyzed had the following original label pasted on the back of it:

Grüner Allagite in Tomosite eingewachsen.
73.71 Manganoxydulat.
16.00 Kieselerite.
7.50 Kohlensäure.
97.21

Schebenholz bei Elbingerode.

This analysis was published in 1817 and 1819 (Jashe 13: 1–12) and to all appearances is the same mineral analyzed by the writer, which is also labelled allagite.

Another part of the same specimen is a greenish jaspery mineral similar physically to the green band of the Newfoundland specimen and has the following composition:

		Recalculation.	
SiO_2	76.40	SiO_2	69.84
Fe_2O_3	.007	$MnCO_3$	10.00
Al_2O_3	2.46	$MnSiO_3$	8.00
MnO	10.53	$MgCO_3$	3.79
CaO	1.62	$CaCO_3$	2.80
MgO	1.81	$2H_2O \cdot Al_2O_3 \cdot 2SiO_2$	6.11
H_2O	.80		100.54
CO_2	7.32		
	100.947		

According to the recalculation this material is a manganiferous argillaceous chert, and is in all probability the silicious schist or shale of the Culm referred to later on.

The third portion of the specimen analyzed is a pinkish sparry mineral occurring as small veins with the following composition:

		Recalculation.	
SiO_2	7.10	$MnCO_3$	76.13
Fe_2O_3	.62	$MnSiO_3$	8.92
Al_2O_3	.76	$CaCO_3$	4.00
MnO	52.01	$MgCO_3$	2.44
CaO	2.26	SiO_2	2.16
MgO	1.17	Fe_2O_3	.37
H_2O	1.70	$2H_2O \cdot Al_2O_3 \cdot 2SiO_2$	5.98
CO_2	32.20		100.00
	97.82		

This mineral, because of its similarity to another specimen with

a label which reads "Spathiger Diallogit" pasted on it, is probably diallogit. It is however a very impure rhodochrosite.

According to W. Holzberger (11: 383) and C. Zerrenner (25: ?—) the ores from the Kaiser Franz mine near Elbingerode, in the Harz, occur as pocket-shaped intercalations a meter or so thick in the silicious shales of the Culm. The ore consists of psilomelane in dense and botryoidal masses, some pyrolusite and coatings of wad, with rhodonite, rhodochrosite and quartz present as accessories. The ore formerly worked contained on an average 60 to 63 per cent. of manganese peroxide, sometimes rising to 67 per cent. (23: 250). Zerrenner considers these manganese ores as later material separated out of the silicious shales, a theory which needs further investigation. Though the above described deposit is not the same as that from which the specimens analyzed above came from, it is no doubt similar.

The Elbingerode occurrence is similar to the deposits of SE. Newfoundland in that they are both primary manganiferous sediments. They differ in that the manganiferous zone of the former occurrence is considerably regionally metamorphosed while the Newfoundland sediments show very little change in this way. According to the above analyses, assuming that the imported specimens are representative of the region concerned, the deposits are very different in as much as they consist mostly of rhodonite and manganiferous cherts while those of Newfoundland are carbonate-oxides and oxide-carbonates of manganese.

VI. CHEMISTRY OF THE MANGANESE DEPOSITS.

The most striking feature of the accompanying analyses is the high content of MnO which ranges from 19.42 per cent. in **Analysis J,** to 49.25 per cent. in **Analysis D,** with an average content of 30.02 per cent and an average metallic manganese content of 24.64 per cent.

The manganese is present for the most part as the carbonate, $MnCO_3$ or rhodochrosite, which varies from 10.23 per cent. in the red band (**Anal. E**) to 44.39 per cent. in the green band (**Anal. A**) of the Manuels deposit. Rhodochrosite is not recognizable as such because of the impalpable fineness of grain of the deposit.

Solubility tests made of the red band (**Anal. E**) which has 27.61 per cent. of SiO_2, in which HCl was used as the solvent, show that the manganese must be present in some other combination than in that of the silicate, as the residue was about sufficient to cover the total silica, SiO_2, Al_2O_3 and P_2O_5. In **Anal. D,** it is evident that the two most important constituents are $MnCO_3$ and MnO_2 with percentages of 32.89 and 28.93 respectively and that the excess manganese calculated as the oxide is more than sufficient to form an important manganese silicate as the mineral percentage of SiO_2 is only 5.40, which fact lends support to the result of the solubility test made with the red band, **Anal. E.** A similar interpretation might be made with the Topsail ore (**Anal. I**) which is primarily an oxide ore with MnO_2— 34.25 and $MnCO_3$— 11.27. SiO_2, of which there is 10.32 per cent., probably is present in an uncombined state. The comparative instability of $MnCO_3$ would, however, lead one to suspect that the excess MnO_2, where not of primary origin, was a derivative of the carbonate and not combined with SiO_2 to form the silicate, $MnSiO_3$.

Analyses of Manganese Deposits of Newfoundland and Elbingerode.

	SiO_2.	Fe_2O_3.	FeO.	Al_2O_3.	MnO.	CaO.	MgO.	$BaSO_4$.	P_2O_5.	H_2O.	CO_2.	Total.
Manuels:												
A, Green band	7.24	3.36	3.21	6.11	35.53	11.30	2.30	....	.....	2.98	28.06	100.09
B, Pink nod. . .	5.14	1.40	....	1.64	20.49	32.92	.01	....	.....	1.65	36.77	100 02
C, Green nod. .	10.31	7.35	....	3.68	31.76	10.47	1.80	6.43	.....	2.85	25.31	99.96
D, Brown band	10.23	1.32	.89	4.14	49.25	8.11	3.02	....	.....	1.31	21.83	100.10
E, Red band . .	27.61	4.25	1.69	6.96	26.05	9.94	3.49	....	4.71	4.73	10.57	100.00
F, 219 A 11 . . .	18.42	6.33	....	7.95	21.44	14.46	5.01	....	3.46	2.58	21.20	100.85
G,* 219 A 3 . . .	58.62	3.12	3.66	22.42	.43	1.25	.26	....	.....	.54	3.99	94.29
H, 219 A 13. . .	25.20	10.13	....	7.67	.....	23.50	4.78	....	17.68	2.71	2.23	93.90
Topsail:												
I, 219 E 4.	18.04	4.82	....	6.58	41.26	2.24	2.39	5.40	.....	7.98	8.34	97.05
J, 219 E 6.	18.24	10.01	....	14.52	19.42	13.74	4.94	....	1.71	2.07	24.01	99.66
K, Smith Pt. . .	15.14	9.22	....	12.04	25.63	10.04	3.72	....	1.26	2.73	21.05	100.83
Elbingerode:												
L, Elbin. (−) .	39.10	1.87	....	10.79	27.69	1.00	6.08	....	.....	1.13	13.13	100.79
M, Elbin. (+)	76.40	.007	....	2.46	10.53	1.62	1.81	....	.....	.80	7.32	100.94
N, Elbin. (=).	7.10	.62	....	.76	52.01	2.26	1.17	....	.....	1.70	32.20	97.82

* Analyst, Mr. A. F. Buddington.

The evolution of Cl during the digestion of the samples with HCl is evidence that the excess Mn occurs as some peroxide. As

there is considerable water in the Topsail ore (**Anal. I**), the excess manganese probably is present as a hydrated peroxide such as psilomelane but probably in a very fine state of dissemination. The remarkable feature of the samples studied is the conspicuous absence of the dark oxides of manganese so far as macroscopic and microscopic observations are concerned but the reason for this may be, in the case of the lighter samples, anyway, that where there are abundant hematitic spherules there may be some masking. With the darker specimens studied, such as the red and brown bands at Manuels and the baritic manganese ore of Topsails (Figs. 22 and 32), the conspicuous manganiferous and ferruginous staining might easily mask finely disseminated particles of the peroxide of manganese.

RECALCULATED ANALYSES.

	$MnCO_3$.	$MnSiO_3$.	MnO_2.	$CaCO_3$.	$MgCO_3$.	$Ca_3(PO_4)_2$.	SiO_2.	Fe_2O_3.	$BaSO_4$.	H_2O.	Clay.	Total.
RA	44.39	.....	8.08	20.11	4.21	.....	.....	3.36	....	.86	18.24	99.2
RB	29.32	.....	2.34	58.05	29.32	.....	3.78	1.40	....	1.06	4.07	100.02
RC	39.56	.....	7.30	18.61	3.79	.....	5.94	7.35	6.29	1.51	9.17	99.52
RD	32.89	.....	28.93	14.01	5.90	.....	5.40	1.27	....	.72	11.08	100.20
RE	10.23	.....	19.71	7.50	7.25	10.31	19.44	4.25	....	1.87	19.01	99.57
RF	19.22	.....	9.36	18.61	10.54	7.50	9.18	6.22	....	.....	19.61	100.24
RG												
RH	.....	.....	.....	4.70	9.19	38.77	16.20	10.06	....	.....	19.11	98.03
RI	21.27	.....	34.25	4.00	4.97	.....	10.32	4.82	5.40	5.41	16.30	96.74
RJ	16.79	.....	.....	20.91	10.37	3.75	1.20	10.01	....	.....	36.38	99.41
RK	26.91	.....	9.00	15.21	7.75	2.50	.84	9.22	....	.....	30.06	101.49
ELBINGERODE												
RL	15.05	33.98	.....	1.70	12.64	.....	10.97	1.75	....	.....	23.76	99.85
RM	10.00	8.00	.....	2.80	3.79	.....	69.84	.....	....	.....	6.11	100.54
RN	76.13	8.92	.....	4.00	2.44	.....	2.16	.37	....	.....	5.98	100.

The two most conspicuous mineral associations of the manganese deposits of southeastern Newfoundland are the tricalcium phosphate, $Ca_3(PO_4)_2$, and barite, $BaSO_4$. Only a few of the beds were analyzed for the former of these constituents where percentages of $Ca_3(PO_4)_2$ ranged from 2.50 at Smith Point (**Anal. K**) to 10.31 (**Anal. E**) at Manuels. **Anal. H** shows 38.77 per cent. of $Ca_3(PO_4)_2$, references to which are made on pages 409 and 453. It

is quite probable that others of the manganiferous beds analysed are phosphatic.

Barite ($BaSO_4$) is probably more common than the analyses indicate and is probably included with the SiO_2 and CaO. It is a conspicuous associate of these deposits, as has been found to be the case with manganese deposits in other parts of the world. The chemical reason for this association of two very different chemically-acting elements, as well as the genesis of barite are discussed on pages 451–453.

Al_2O_3, though not as abundant in the important manganiferous beds as in a typical shale, which that of **Anal. G** approximates, is of sufficient abundance to connect these deposits with the argillaceous sediments. CaO and MgO are in greater amounts than in ordinary shales, giving the deposits a calcareous or dolomitic character.

From a study of the mineral percentage composition of the samples analysed, the manganese rocks are found to be essentially calcareous or dolomitic argillaceous carbonates and oxides or carbonate-oxides of manganese, with hematite, barite, and tri-calcium phosphate as the chief accessories.

The following iron determinations of the green and red shales of the manganese zone at Manuels, Conception Bay, show some interesting results.

	FeO.	Fe_2O_3.
Red shale, 210 A 4	4.58	3.86
Green shale, 219 A 3	3.66	3.12
Red band, 219 A 7	1.69	4.25
Green band, 219 A 7	3.21	3.36

It is quite evident from the above analyses that the color in the green shale A 3 and in the green band A 7 is not due entirely to the ferrous iron as we find considerable Fe_2O_3 in both. In the green shale, A 3, there is an excess of .54 per cent. of FeO over the Fe_2O_3, while in the green band, which is manganiferous, there is an excess of .15 per cent. of the ferric oxide (hematite) over the ferrous oxide. In the green band we should expect a masking of the green by hematite inasmuch as there is such an excess of the ferric over the ferrous. Thin sections of this band and the green shale reveal some hematite but in very inconsiderable amounts; not enough, at

all events, to explain the percentages as brought out in the analyses. It would seem then that the ferric iron does not exist essentially as hematite but as a silicate or some other allied mineral, and that the green color so predominant in the manganese bands and shales may be due to the ferrous and ferric silicate.

The presence of hematite in the red band has undoubtedly caused the red coloration and the same may be said in reference to the red shale, 210 A 4, where there is an excess of .72 of FeO over the Fe_2O_3, but in these there undoubtedly has been sufficient masking of the ferrous and ferric silicates of iron by the hematite.

The production of the hematite was probably brought about by the conversion of the silicate into Fe_2O_3 through oxidation.

VII. GENESIS OF THE MANGANESE DEPOSITS AND ASSOCIATED MINERALS.

So many of the sedimentary manganese deposits described in the literature are in such a highly altered condition because of oxidation and deeper seated metamorphic influences whereby the original or primary manganese minerals have been so altered as to be of little genetic significance, that the carbonate-oxide manganese ores of southeast Newfoundland, which are surely primary ores, give promise of yielding evidence of considerable value on the question of genesis. In considering the genesis of any marine sedimentary manganese deposits, we are, however, confronted with many grave difficulties because we are dealing with submarine chemical conditions of which little is known and with diagenetic processes of which still less is known. It is also very difficult to advance any suitable chemical hypothesis founded upon some reaction that successfully works out in the laboratory which will not be of doubtful application in nature. With these difficulties in mind the following subjects relating to the genesis of the manganese deposits of southeast Newfoundland will be considered: Early Cambrian physiography; Nature of deposited sediments; Conditions under which the manganese deposits were formed; Summary of genesis of manganese; Diagenetic structures, as banded, nodular and oölitic; Genesis of barite; Genesis of tricalcium phosphate; Association and separation of iron.

EARLY CAMBRIAN PHYSIOGRAPHY.—In all probability the area occupied by Trinity, Conception, Placentia, and St. Marys Bays, the included land and the western and eastern margins including the present known Cambrian outcrops, was a continuous body of water shortly after the beginning of the Cambrian transgression. West and east of this Cambrian sea were high and extensive pre-Cambrian land areas. The great crustal movements which threw the pre-Cambrian into mountain ranges probably converted the portion now occupied by the four bays and adjacent land into a narrow basin. The main topographic features of the southeastern part of Newfoundland during the beginning of the Cambrian were two land areas of great relief separated by a comparatively narrow trough which had a general north-south direction.

Whether this trough was a closed one or not, it would be difficult to prove, but from the requirements of the problem it is necessary to postulate a more or less closed basin or coastal shoals or lagoons, Concentration of manganiferous soluble salts could go on satisfactorily only in a more or less restricted shallow sea where the water was comparatively quiet. The facts that ripple marks occur occasionally in the deposits such as at Manuels and that a shallow water fauna abounds such as trilobites are sufficient indication that there was a shallow sea at this time.

NATURE OF DEPOSITED SEDIMENTS.—Into this trough during early Cambrian times great quantities of mud were brought by rivers draining the pre-Cambrian land masses and to a lesser extent by the action of the waves on the shore line. As has already been stated the greater thickness of shales in the western portion of the basin is due to the fact that sedimentation had been going on for a longer time in that part of the basin which was in all probability the deeper part. It is also quite possible that the western parts of this trough were receiving more sediments than the eastern. The shales are characterized by their predominant red color in the western parts of the basin interbedded with shales of green color and throughout the entire area by a highly manganiferous zone.

GENESIS OF THE MANGANESE ORE.—The distinctly bedded character of the manganese deposits and their occurrence in definite horizons of limited thickness and considerable horizontal range seem

to point clearly to the conclusion that the deposits are essentially of sedimentary origin, rather than products of a later ground water or weathering concentration. But beyond this conclusion, there is room for great diversity of opinion.

Two questions present themselves at the outset of the inquiry: Was the manganese deposited contemporaneously with the clastic sediments in its present degree of concentration? Or, was it somewhat disseminated through the muds and subsequently concentrated by diagenetic agents? While the first of these alternatives is held by the writer to be highly probable, no positive and final answer can be given to these and to many other questions raised by a study of the problem of genesis, although various suggestions are presented in the following pages.

Manganese exists in sea-water and has been noted by Forchhammer and by Dieulafait (6: 718) but not in sufficiently concentrated form to produce deposits similar to those under consideration. Murray and Irvine (19: 735) found that the red muds of the mid-Pacific and Indian Oceans, which were made up in large parts of basic vitreous volcanic minerals, were responsible for the large amounts of pulverulent and nodular ferromanganese. These nodules consist on the average of 29 per cent. of MnO_2 and 21 per cent. of Fe_2O_3 with the remainder largely clayey material. The basic glasses contain the only important primary manganese-bearing minerals in the ocean and the manganese is reported by Murray and Irvine to have undergone conversion into the soluble bicarbonate which upon reaching oxygenated surface waters, is decomposed with precipitation of the dioxide. The particles of MnO_2 falling to the bottom gather upon various objects which serve as nuclei for concretions, or the nuclei themselves may have been the cause for the precipitation. Murray and Hjort (17: 192) in this connection say:

> "It should be noted that these oxides need by no means necessarily assume a concretionary form. They are very commonly found as thin incrustations on granular and fragmentary objects. Furthermore many, if not most, of the pelagic clays contain intimate admixtures of finely divided brown manganese and occasionally of limonitic iron. Here the supersaturation would seem to have been so high as to transgress the metastable limit, whereupon the oxides have precipitated themselves without the intervention of nuclei; they certainly must have been precipitated from solution."

According to Leigh Fermor (8: 403) the origin of the deep-sea nodules is summed up as follows:

"1. The manganese, although probably partly derived from cosmic dust and volcanic débris, has been mostly precipitated from solution in the sea water, the manganese salts having been originally brought into the sea by rivers.

"2. The manganese oxide, although possibly partly precipitated as a result of the action of the vital processes of organisms, both vegetable and animal, has been mainly precipitated by calcium carbonate aided by the obscure process of segregation from solution round a nucleus.

"3. Where the sea-bottom consists largely of calcareous sediments, the precipitation may have been mainly brought about by the solution of some of this calcium carbonate with the deposition of an equivalent amount of manganese oxide owing to the presence of free oxygen.

"4. Where the sea-bottom consists of red clay, it does so because the depths are there so great that the tests of thin-shelled organisms are completely dissolved by the sea-water before they reach the bottom. The calcareous matter in being dissolved deposits an equivalent amount of manganese oxide, which descends to the bottom, and there acts as a nucleus for the segregative extraction of manganese from the waters at the sea-bottom. The deposition of manganese oxide by means of calcium carbonate associated with the red clays probably also occurs to a subordinate extent, for the shells of thick-shelled organisms may reach the bottom before being entirely dissolved."

This summary of Fermor's is quoted in full here because of the marked divergence of his views from those of Murray and Irvine, and because of the greater stress laid upon Penrose's idea of the precipitation of manganese oxide by calcium carbonate.

It is the belief of the writer that the early Cambrian Sea of southeastern Newfoundland must have had so restricted and shallow a character as to allow of a concentration of the manganese salts sufficient to form deposits of such dimensions and character as we now find. Whether the manganese was brought down entirely in solution or only partially so, or entirely or partly in mineral combination as fine muds from which the manganese was subsequently dissolved, one cannot say at present. Both muds and solutions probably have contributed the manganese which forms in great part the deposits as we now find them.

The conditions which brought about the formation of the carbonate and oxide of manganese are problematical. It is generally

supposed that manganese exists in solution as a bicarbonate or a sulphate. In their work on the Blue Muds of the Clyde Sea area, Murray and Irvine (19: 728) found that the bicarbonate of manganese was derived "first from the direct decomposition of the rock fragments in the mud by the alkaline carbonates in the sea water or, second, from the reduction of the higher oxides of manganese by the organic matter in the muds." In many respects the Clyde Sea area of England is similar to what the lower Cambrian sea of Newfoundland must have been. It receives detritus and waters draining lands which are in large part of an igneous and sedimentary character (19: 780).

> "What is known as the Clyde Sea Area consists of a series of submarine basins, separated from each other by submarine barriers. The depth of the basins ranges from 30 to 106 fathoms, and the depth of water over the intervening ridges varies from 3 to 15 fathoms. In all the deeper parts of the basins there is a bluish mud, in which, as a rule, no manganese nodules are found, but on the immediate surface of the deposit of Blue Mud there is a surface layer with a reddish or light gray color, in which deposits of manganese dioxide occur. When stones are dredged from these muds many of them are surrounded by a dark ring of manganese dioxide, marking the depth to which they have been embedded in the mud. The whole upper surface of the stones has likewise a slight coating of manganese, while a portion imbedded in the mud is free from these manganese deposits."

He goes on to say that

> "The formation of manganese nodules on the immediate surface of the deposit, on the tops of the barriers, and in the pit-like depressions, is most probably to be accounted for by the more abundant supply of oxygen, or the diminished amount of decomposing organic matter in these positions."

A somewhat similar set of conditions probably was present in the muds and superjacent sea water of the Cambrian basin of Newfoundland with the exception that instead of all the bicarbonate being converted into the dioxide the greater proportion of it was precipitated as the carbonate of manganese ($MnCO_3$). The liberation of CO_2 from the bicarbonate of calcium in solution has been experimentally effected by evaporation, increasing the temperature, or through agitation of the solution. It would seem to the writer that the liberation of the CO_2 from the manganese, calcium and magnesium bicarbonates might have taken place through evapora-

tion resulting in a contemporaneous formation of manganese, calcium and magnesium carbonate. As the analyses show from 1.25 to 32.92 per cent. of $CaCO_3$ and from .01 to 5.01 per cent. of $MgCO_3$ this would seem to support such an action.

There is a possibility that the decomposing organic matter present in the muds might have caused a deoxidation of the sulphates of the sea-water and of MnO_2 with the subsequent formation of FeS_2 and MnS_2. The latter, being very unstable, would pass immediately into the bicarbonate to be subsequently freed of its CO_2 to form the carbonate and if oxidized would pass into the dioxide. Such a process might account for the carbonates and oxides of manganese and the little pyrite that occurs. Though there is evidence of life in the manganese deposits of Newfoundland as furnished by the fossil trilobites, pteropods and phosphatic accumulations, we have no evidence that there was any great abundance. However these deposits resemble the Blue Muds studied by Dittmar (6: 43) which are a variety of terriginous deposit which

> "covers about 15,000,000 square miles of the sea bed, and is chiefly found in estuaries, harbours, enclosed seas, and along continental coasts where rivers pour their detrital matter into the ocean."

According to the "Challenger researches" there is an abundant fauna on these muds, which feeds chiefly on the organic remains that fall from surface waters. If any analogy can be made between the ancient terriginous deposits and the more modern ones such a chemical action as described above might very well have taken place.

If the muds on the bottom of the basin contained considerable quantities of decomposing organic matter, conditions would favor a reduction of the higher oxides of manganese, the evolution of much CO_2 and the consequent formation of the bicarbonate of manganese. The subsequent liberation of the excess CO_2 from the bicarbonate to form the carbonate and, where oxidizing influences are active, the oxidation of this carbonate would complete a series of reactions capable of forming the manganese deposits with which we are dealing. It is very probable that these muds contained considerable quantities of decomposing organic matter and were evolv-

ing considerable CO_2. According to the "Challenger researches," when a large quantity of carbonic acid was found in oceanic waters it was "at the bottom over Blue Muds." The great difficulty in this series of reactions is to find in nature the conditions which will bring about the liberation of the excess CO_2 from the bicarbonate to form the carbonate, such as evaporation, increase of temperature, or agitation. If quiet waters are postulated for the formation of manganese carbonate it is quite conceivable that either of the conditions such as evaporation or an increase of temperature might easily be obtained particularly in shoal waters. It is very doubtful, however, in the case of agitated waters whether laboratory conditions can be simulated in nature, because of oxidizing influences whereby some oxide of manganese would form more readily than a carbonate. After the carbonate had formed there would be no particular difficulty in conditions being present which would bring about the oxidation of the carbonate because of the presence of oxygen. The excess oxide of manganese found in the Newfoundland deposit may in part have originated in this way.

Penrose (20: 563) suggested that "carbonate of lime on the sea floor may have acted as a precipitating agent" or as it passes through the sea-waters in the form of organic remains or mineral particles a substitution takes place whereby a solution of the calcium carbonate with a corresponding precipitation of manganese occurs. Fermor develops this suggestion in his explanation of the origin of the deep sea nodules as quoted on page 444. Such an explanation might apply to the origin of the primary oxides of the Newfoundland deposits.

It is possible that manganese may have been present in the sea-water as a chloride. L. De Launay (5: 533) says that "manganese chloride with sodium bicarbonate produces manganese carbonate."

When we stop to consider that manganese only averages .07 per cent. of the lithosphere (Clark, 2: 32) and is 70 times less abundant than iron which averages 4.43 per cent. and compare with these figures the percentage of manganese in the deposits under consideration which is 24.64 we can obtain some idea of the enormous concentration there has been in the production of these deposits.

We have discussed the nature of the sediments and learned that these terriginous deposits must have been derived from the pre-Cambrian land masses which existed in far greater extent on the east and west of the Cambrian sea than the present areas outlined on page 373. The interbedded character of the manganiferous and argillaceous layers signify alternating conditions of chemical precipitation and mechanical deposition, there being, during the formation of the deposits, times when the Cambrian sea was more manganiferous with conditions such that precipitation of manganese carbonate and the oxide was the relatively important feature while, at other times, mechanical deposition of fine muds was the rule. It is more than likely that the greatest portion of the manganese was contributed to the sea in the form of the dissolved bicarbonate by the streams which transported the clastic sediments and that these sediments were not themselves responsible for the major contribution, though undoubtedly the manganese minerals in the muds underwent some solution both during their transit to the sea bottom and during diagenesis. The streams which were responsible for the transportation of the sediments of the manganese deposits and also held, as chief contributors of the manganese, drained the pre-Cambrian land areas above referred to. A modern river like the Ottawa which drains a pre-Cambrian area consisting in great part of Laurentian and Huronian rocks and in all probability not very different from the pre-Cambrian rivers of ancient Newfoundland, has .86 parts per million of manganese in its waters according to an analysis made in 1907 (Shutt, 22: 175).

Manganese in river water results from the solution of manganiferous silicates such as pyroxene, olivine, micas, amphiboles, epidotes and chlorites, some of which are the common and essential basic rock-forming minerals of any igneous and metamorphic pre-Cambrian area. On the decomposition of these elements the manganese is converted into carbonate or oxide and enters into solution, when conditions are favorable, as the bicarbonate, in which form it is carried to the sea, unless oxidized in transit, there to await the further changes into the oxides, MnO_2 and Mn_2O_3, or the carbonate, $MnCO_3$, depending upon the conditions suggested in the preceding pages. Analyses of some of the pre-Cambrian rocks in the vicinity

of Conception and Trinity Bays may be of interest at this point as illustrating the manganese content of some of the rocks which are most like those existing during the formation of the deposits:

	MnO.
Monzonite, Woodford	.19
Quartz porphyry, Manuels	.11
Conception sl., Random Is.	.12
Granite, Manuels	.13
Aporhyolite, Manuels	.12
Basalt, Blue Hills	.48

Analyst, A. F. Buddington.

Similar analyses have been made from the rocks of the Clyde pre-Cambrian drainage area and show from .1 to .7 of a per cent. of MnO (Murray and Irvine, 19: 722). In all probability then the pre-Cambrian rocks on the east and west of the Cambrian basin were the ultimate source of the manganese.

Summary of Genesis of Manganese.

Ultimate Source of the manganese was the manganese-bearing silicates of pre-Cambrian igneous and metamorphic rocks east and west of the Cambrian Sea.

Solution of manganese-bearing silicates and conversion of the manganese into the soluble bicarbonate; under favorable conditions oxides of manganese resulted from the oxidation of the bicarbonate of manganese.

Transportation of the manganese chiefly as the bicarbonate and to a less extent as suspended particles of oxides by pre-Cambrian drainage systems to Cambrian basins.

Concentration of the salts of manganese chiefly as the bicarbonate in the sea-water immediately overlying the deposited muds.

Precipitation of manganese carbonate from solution through liberation of CO_2 from the bicarbonate, or of the oxide.

Clastic Origin of Some Manganese.—While the main contribution of the manganese came from the pre-Cambrian drainage area in solution undoubtedly the deposited muds supplied a minor portion.

Diagenetic Structures

Banded Structures.—By referring to the description of layer 219 A 7 we see that it is a red manganiferous shale with green and brown jaspery bands which may be rather uniform in thickness and may alternate with each other. The green band predominates over the brown so that the greater alternations occur with the green and red bands. Throughout the red shale are numerous nodules of the green and brown jaspery carbonate-oxides of manganese and within the bands themselves are nodular and concretionary forms. The alternating banded and concretionary forms within this bed would indicate alternating conditions of precipitation followed by diagenetic segregational processes which resulted in the formation of nodules and lenticles. Very thin and interrupted laminæ of the red band are found with the green bands. The green and brown bands often occur intergrown with each other. From these observations it would seem that these banded structures were evidence of alternate periods of precipitation and that they have assumed their present indurated and concretionary nature by segregational processes which were active throughout the diagenesis of the bed.

Nodules.—One of the most characteristic features of the shales of the Lower Cambrian is the great prevalence of the nodules (Figs. 14 and 15). The following suggestion is offered as to the origin of the form of these nodules with the hope that this line of investigation may be taken up in greater detail at some future time. Though various theories have been suggested for the origin of oölitic spherules and nodules, in general, along organic and inorganic lines, nothing of a very definite nature has been brought out as to the origin of their form. The suggestion that surface tension may be the cause of this form is here made. This peculiar and prevalent nodular character of certain beds was brought about in all probability by the tendency of surface tension to decrease the surface during the diagenetic stage. Solutions carrying manganese filtering through muds or nearly consolidated muds or shales would quite naturally under certain chemical and physical conditions have the tendency to decrease the surface tension at the contact of the three physical phases; liquid, colloid, and solid. Starting with a

mineral particle such as rhodochrosite or calcite as a nucleus, with the formation of the nodule, there will be a decrease in the concentration of the solution at the contact with the nodule which will be accompanied by a reduction of surface tension. If we are dealing with a liquid-liquid phase we would have a spherical nodule in which case both liquids would be easily deformable and the surface would tend to become a minimum. Our twofold phase, liquid-solid, or threefold phase including the colloidal phase which probably plays a part, only allows of deformability on the part of the liquid and partial deformability on the part of the nodule. Under the bedded conditions of this two or three fold solution, colloid and solid phase the tendency of the surface tension to reduce the surface to a minimum is well exemplified in the discoidal nodule.

Spherules.—One of the characteristic features of this deposit is the occurrence of hematite in spherule-like forms and larger, roughly spherical aggregates. Fig. 26 illustrates the occurrence. They differ decidedly from the spherules of the Wabana, Clinton, and other typical oölitic iron ores in that they are less symmetrical and are without any visible nuclei. These spherules are here described as incipient in as much as they seem to lack full development or to have been impeded in their growth. Such a retardation of development might have arisen from their growth in clayey sediments which were still unconsolidated.

Mineral Associations.—The three important mineral associaciations of the manganese deposits of S. E. Newfoundland are barite, tri-calcium phosphate and hematite which will now be considered with reference to their occurrence, association and genesis.

Barite.—Barite is one of the most characteristic mineral associations of the deposits under consideration as is often the case with manganese deposits elsewhere in the world. It is particularly characteristic of the Manuels, Topsail and Smith Point localities and occurs in various ways.

Barite is found in small veins crossing a cryptozoan nodule showing quite clearly its epigenetic character so far as that particular portion of the bed is concerned. Fig. 23 (Slide 276) shows a solitary crystal fragment of barite in a carbonate-oxide of man-

ganese groundmass showing possibly a diagenetic replacement. Barite also occurs as disseminated anhedral crystal grains or blades in the cores and outer zones of nodules at Manuels, which is very suggestive of diagenetic processes (Fig. 16, Slide 288). At Topsail (Fig. 31, Slide 269) barite occurs as bundles of blades or sheath-like aggregates in a manganese oxide groundmass strongly suggesting replacement.

In other parts of the world barium is often found replacing manganese in psilomelane and sometimes enters largely into the composition of wad, specimens from Romanèche containing as much as 16.2 per cent. of BaO (Dana, 3: 258). A very striking phenomenon shown by the barite is its replacement by chlorite (Fig. 12, Slide 296, and Fig. 34, Slide 272).

Just why there is this common association of two very unlike elements we have no definite information. De Launay (4: 52) gives the following explanation for epigenetic deposits:

> "The association between barite and manganese though very frequently exhibited in surface formations, in many cases these two substances are being concentrated by circulating waters in pockets or fissures of terranes."

Various conditions may produce barite with barium salts in solution but only one seems to apply to the occurrences under consideration. As there are evidences of diagenetically and epigenetically formed barite in the deposits, it is quite possible that there has been an intermingling of solutions carrying barium carbonate and some sulphate resulting in the formation of barite. According to De Launay (4: 52)

> "Barite being remarkably insoluble is one of those barium compounds which not only has the propensity to segregate and all at once to be transformed into the carbonate but also the tendency under the influence of H_2SO_4 produced by the superficial oxidation of the metallic sulphides to pass into the state of barite."

The replacement of the colorless barite by the pale green chlorite begins about the edges and along cleavage cracks of the former. The chlorite gradually spreads while the intervening portions of barite decrease until wholly eliminated, resulting in a pseudomorph of chlorite after barite. In general appearance of its various stages,

the process is quite like the serpentinization of olivine but differs essentially from the latter alteration in the fact that the secondary mineral, chlorite, derives none of its material from the original mineral, barite, its change involving a complete replacement by wholly new material. It is a marked example of the comparative ease with which substances which, like barium sulphate are regarded in the laboratory as very stable, yield to the attack of natural reagents.

This replacement seems to have accompanied a more or less general chloritization of the whole formation, at a period long subsequent to the concentration of the manganese ore and under totally different conditions.

PHOSPHATE.—Tri-calcium phosphate, $Ca_3(PO_4)_2$ also is a very conspicuous accessory of the manganese deposits of Newfoundland, averaging, for those beds of which analyses were made, about 6.0 per cent. and for the phosphatic nodules of the nodular bed overlying the manganese zone at Manuels, 38.77 per cent. When we stop to consider the amount of phosphorus in the lithosphere as .11 per cent. (Clark, 2: 32) the amount of concentration in these deposits, particularly in the nodules, becomes very noticeable and something of great interest. The similarity in chemical composition of the phosphatic nodules of Manuels brook and those of Hanford brook, N. B., has been referred to on page 409. As the writer has been unable to make as thorough a study of these nodules as he would have liked, it is hoped that at some future time the investigation may be continued. At this time then a very brief resumé of the modes of concentration of phosphorus may be of interest because of apparent application to the deposit under consideration.

According to De Launay (5: 646) there are three stages in the concentration of phosphatic deposits, namely solution of calcium phosphate, in which he considers that in surface conditions

> "the constant presence of carbonic acid and sodium chloride or chlorhydrate of ammonia in the waters determines the solution of phosphate."

The second stage is that in which organisms play an important rôle.

"The faculty which live organisms have of throwing into very dilute solutions those substances which to them are necessary and of making them undergo a primary stage of concentration has played a great rôle for the phosphates." De Launay (5: 646).

The third stage called by De Launay, "Remises en mouvement" consists in a dissolution of the phosphate contained in preceding deposits which is followed by a reprecipitation of the same upon anything which has served as a center of attraction. The tendency in this mode of concentration is for the phosphate to become more and more like the original apatite in composition, the ultimate source of the phosphorus. It involves both a chemical and a mechanical action, the former in dissolution and reprecipitation and the latter in the formation of nodules which, according to the suggestion of the writer in connection with the manganese nodules of Manuels, may be of physical nature, namely the result of surface tension.

IRON.—An interesting, and yet problematical, point arises here in connection with the association and separation of iron and manganese as related to the manganese deposit under consideration. We should expect, in as much as both elements are taken into solution, that they both might be precipitated together as is sometimes the case with bog ores or, if separated, at no great stratigraphic distance. Because of their different rates of oxidation and different degrees of solubility, however, a separation is effected. Assuming both elements entering into solution contemporaneously, the iron would oxidize first, precipitating as Fe_2O_3, while the manganese, remaining in solution longer, is precipitated either as MnO_2, Mn_2O_3 or $MnCO_3$. Though the Newfoundland manganese deposits contain iron, it is much less in proportion to what it would be if both were precipitated together (see Analyses, p. 438) considering the relative abundance of the two elements in the lithosphere referred to on page 447.

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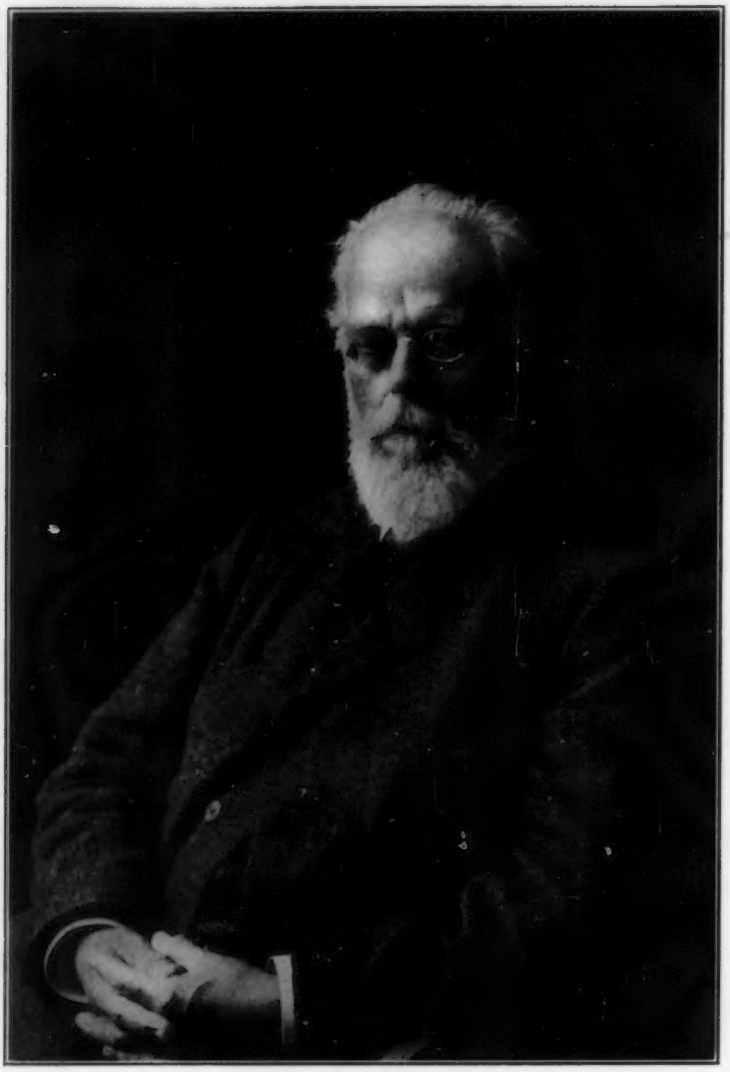
Princeton University,
June, 1914.

OBITUARY NOTICES
OF MEMBERS DECEASED.



AUGUST WEISMANN.

BORN JANUARY 17, 1834. DIED NOVEMBER 6, 1914.

AUGUST WEISMANN.

PLATE A.

(Read January 1, 1915.)

August Weismann, a foreign member of this Society, was born at Frankfort on the Main, January 17, 1834, and died at Freiburg in Breisgau, November 6, 1914. He early showed the traits of a naturalist and in one of his books speaks of the excitement he felt as a boy in catching butterflies. He attended the University of Göttingen, where he studied chemistry and medicine, coming especially under the instruction of the distinguished anatomist Henle, and receiving the degree of M.D. in 1856. After spending three years at Rostock as an assistant he began the practice of medicine at Frankfort and during this time he visited Vienna in 1858, Italy in 1859 and Paris in 1860. From 1861 to 1862 he was private physician to Archduke Stephan of Austria at Schamburg Palace. He then studied zoölogy at Giessen under the renowned zoölogist Leuckart and became *privat-docent* in zoölogy at the University of Freiburg in 1863, where he spent the remainder of his life. In 1866 he was appointed *professor extraordinarius* and a few years later became *professor ordinarius,* which position he continued to hold until a few years before his death, when he was made *professor emeritus.*

In person he was a man of striking appearance, being about six feet tall and well proportioned and having a fine head and face and an earnest but kind expression of the eyes. From 1864 to 1874 and again from 1884 on he suffered from an eye trouble which interfered greatly with his microscopical work and turned his attention to theoretical questions. One of his former students and assistants, Professor Alexander Petrunkewitch,[1] to whom I am indebted for much valuable information concerning his personality,

[1] I am also indebted to Prof. H. H. Wilder, of Smith College, and to Prof. J. S. Kingsley, of the University of Illinois, for information regarding the family life and personality of Weismann.

says that although he was usually quiet in manner he invariably became nervous and unhappy in the presence of moving objects, which painfully affected his eyes.

A short autobiography published in *Lamp* in 1903 gives a glimpse of his family life:

> "During the ten years (1864–1874) of enforced inactivity and rest occurred my marriage to Fraulein Marie Gruber, who became the mother of my children and was my true companion for twenty years until her death. Of her now I think only with love and gratitude. She was the one who more than any one else helped me through the gloom of this period. She read much to me at this time, for she read aloud excellently, and she not only took an interest in my theoretical and experimental work but she also gave practical assistance in it."[2]

His great work on the "Natural History of the Daphnoidea" (1876–79) is dedicated to "My father-in-law, Adolph Gruber, in thankful memory of the beautiful hours of leisure spent on the shores of Bodensee." His colleague, the anatomist Wiedersheim, married another daughter of Gruber who was a Genoese banker. After the death of his first wife Weismann married again when about sixty years old, but not happily. One of his daughters married the zoölogist W. N. Parker, who translated into English his best known work "The Germ Plasm." A son was trained as a professional violinist.

Weismann, like so many other naturalists, was of an artistic disposition. He loved nature, art and music and he was an accomplished pianist. During the periods when he suffered much from his eye trouble he says that he "found solace in playing a good deal of music." He was an enthusiastic admirer of Beethoven but could not appreciate Wagner. His artistic temperament is further shown in many of his essays which for beauty of expression are rarely surpassed in scientific literature.

He was an excellent speaker, being simple and earnest in manner and never indulging in jokes. His lectures on evolution, which were delivered regularly for almost forty years, were famous and always attracted great audiences. As a teacher of advanced students he was stimulating and helpful, a kind critic and an attentive listener.

He took no active part in politics, but like many German pro-

[2] Quoted from Locy's "Biology and its Makers," p. 401.

fessors was a member of the "National Liberal" party. In philosophy he held tenaciously to a mechanistic conception of nature, but he believed that extreme mechanism was consistent with extreme teleology, indeed he held that "The most complete mechanism conceivable is likewise the most complete teleology conceivable. With this conception vanish all apprehensions that the new views of evolution would cause man to lose the best that he possesses—morality and purely human culture." In his philosophy as in his scientific controversies he was extremely tolerant. He was interested in the promotion of knowledge but was not aggressive nor offensive in manner.

Inasmuch as his life was so largely given to the extension and support of the Darwinian theory it is interesting to hear from himself how that theory first came to his attention. After remarking, "I never heard evolution referred to in my student days," he describes the influence on himself of Darwin's book in these words:

> "I myself was at the time in the stage of metamorphosis from a physician to a zoölogist, and as far as philosophical views of nature were concerned I was a blank sheet of paper, a *tabula rasa*. I read the book ["Origin of Species"] first in 1861 at a single sitting (*sic*) and with ever growing enthusiasm. When I had finished I stood firm on the basis of the evolution theory, and I have never seen reason to forsake it."

With just pride he mentions the fact that he was one of the first scientific men in Germany to defend publicly Darwin's theory; Fritz Müller was the first to publish a work in favor of that theory ("Für Darwin," 1864), Haeckel was the second ("Generelle Morphologie," 1866) and Weismann was the third, his Inaugural Address at Freiburg on the "Justification of the Darwinian Theory" ("Über die Berechtigung der Darwin'schen Theorie") being published in 1868.

Thereafter his contributions to the Darwinian theory were numerous and important. They appeared from 1872 to 1902 as a series of books and contributions. Five of these earlier contributions were translated into English by R. Meldola and were published as two large volumes in 1882 with an introduction by Charles Darwin. Subsequent studies on evolution were so intimately associated with his theories of heredity that they can best be considered under that topic.

Weismann's contributions to biological theory were so extensive and important that they overshadow to a great extent his observational and experimental work, and yet the latter was by no means small or unimportant. Among these observational and experimental studies must be mentioned especially his extensive works on "The Development of Diptera (1865)," "Natural History of the Daphnoidea" (1876–79), "Origin of the Sex Cells of the Hydromedusæ (1883)," "Seasonal Dimorphism of Butterflies" (1875), "Origin of Markings of Caterpillars" (1876) and "Transformation of the Mexican Axolotl into Amblystoma."

Some of his earlier work was done without assistance, but in all of his later observational and experimental studies he had the assistance of his wife or other helpers. Much of his work was done in collaboration with some of his students or assistants. His method of work was to a large extent forced upon him by his eye affliction. After 1864 all reading had to be done for him, at first by his wife and after her death by a secretary. Experimental work was done under his supervision by his assistant and janitor. All microscopic work was done by his pupils, to whom he suggested topics and whose work he supervised daily. These theses were always in direct relation to his theories and to that phase of them which interested him most at the moment.

But valuable as much of his observational and experimental work was, there is no doubt that he will be remembered chiefly for his theories of heredity. His earliest writings on this subject date from the year 1883 and his latest were published but a few years before his death. His "Essays upon Heredity and Kindred Biological Topics" were translated into English and published in two volumes in 1889 and 1892. Probably his most important work on this subject is his book entitled "The Germ-Plasm, A Theory of Heredity" which was published in English in 1893. Subsequent works on heredity are "On Germinal Selection" (1896) and "Vorträge über Descendenztheorie" (1902). This last-named work, which was published in English under the title "The Evolution Theory" (1904), consists of a summary and an expansion of many of his previous writings on the subjects of evolution and heredity;

indeed as he says in the preface of this book, it is "a mirror of the course of my own intellectual evolution."

Without attempting to analyze these different books, which would require more time and space than is here available, we may proceed at once to a summary of his more important contributions to the theories of evolution and heredity.

All his theories, both of heredity and evolution, center in what he called the "germ-plasm," that particular part of the germ cells which serves to carry over from generation to generation the inheritance factors. This germ-plasm was held by Weismann to be absolutely *continuous* from the present generation back to the earliest generations of living things; it was absolutely *distinct* from the somatoplasm of the body and the latter could never become germ-plasm; it was almost perfectly *stable* undergoing practically no changes except such as came from the mixing of different kinds of germ-plasm (amphimixis) in sexual reproduction.

These views as to the nature of the germ-plasm underwent some modification as the result of criticism. Weismann was forced to admit that the distinctness and stability of the germ-plasm were not absolute, but in spite of all criticism he was able to maintain that the germ-plasm was relatively very distinct from other plasms and very stable in organization and this is now admitted by all persons acquainted with the subject.

His views as to the separateness of somatoplasm and germ-plasm, of body cells and germ cells, and the mortality of the former and potential immortality of the latter, led him to regard organisms in which this distinction does not exist (many protozoa and protophyta) as potentially immortal. With a keenness of insight which was not appreciated at the time but which has been confirmed by recent work he reasoned that "conjugation like food and oxygen may be conditions of life but immortality does not rest on the magic of conjugation any more than on food or oxygen." Again he anticipated the most recent opinions when he held that death is not a necessary correlative of life, but rather the result of higher differentiation. In short, as Minot said, "Death is the price we pay for our differentiation." On the other hand, his attempt to

explain the origin of death as an adaptation due to selection was probably a mistaken one.

As to the location of the germ-plasm in the sex cells Weismann maintained that it was to be found in the chromatic substance of the nucleus. He held that the chromosomes ("idants") were composed of smaller units, the chromomeres ("ids"), and that the latter were composed of "determinants" or inheritance units, while the most elementary units of life he called "biophores." Both chromosomes and chromomeres are visible structures of the cell. Determinants and biophores are ultra-microscopic in size but recent work on heredity and development has shown that there is good evidence of the existence of such units. All recent work in genetics is based upon the hypothesis that there are units or factors or determiners in germ cells which condition the development of adult characters, and though there may be minor differences between these *determiners* of modern genetics and the *determinants* of Weismann no one can fail to note the genetic connection and the family resemblance between the two.

His prediction on purely *a priori* grounds that one of the maturation divisions in the formation of the egg and sperm should be a "reduction division" whereby the chromosomes of the sex cells should be reduced to half the number present in the somatic cells, whereas all other cell divisions should be "equation divisions" in which the chromosomes should divide equally, was almost as brilliant an example of scientific prophecy as was the prediction of the existence of the planet Neptune.

Similarly Weismann's assumption that the determinants are arranged in a linear series in the chromosomes finds strong support in the newest and most striking discoveries in this field, in which Morgan is able to locate at different points along the length of a chromosome the determiners of many developed characters.

Finally there is at present universal agreement to the declaration of Weismann that no purely epigenetic theory of heredity is possible, though for many years even this was hotly contested. When one recalls the storm of opposition which was called forth by his book on "The Germ-Plasm" the present acceptance, at least

in principle, of his major propositions cannot be viewed in any other light than as a triumph for his theory and a tribute to the insight, foresight and constructive ability of Weismann.

As a result of his theory of heredity Weismann was led to investigate the generally accepted doctrine of the inheritance of acquired characters. He carried on extensive experiments in order to learn whether mutilations of parents through many generations were ever inherited by offspring; he investigated many supposed cases of the inheritance of such characters, and as a result of this work he was led to deny altogether the possibility of the inheritance of acquired characters, and he challenged the world to furnish any satisfactory proof of such inheritance. This work of Weismann's called forth a tremendous amount of discussion and a relatively small amount of direct observation and experiment, and for several years it appeared as if no progress whatever was being made toward the solution of this great question, so full of importance, not merely for the biologist but also for the practical breeder and indeed for the human race. But gradually there has grown up a clearer understanding of the problem and of what is meant by "inherited" and "acquired" characters, and gradually this dead-lock of opinions is breaking up. Now we recognize that inherited characters are those whose distinctive or differential causes are in the germ cells, while acquired characters are those whose differential causes are environmental. No one today believes that the developed or somatic characters of an organism are transmitted to the next generation. Today the problem of the inheritance of acquired characters is merely this: Can changes in the environment change the constitution of the germ-plasm so as to produce changes in subsequent generations? No one now asks whether changes in developed characters may be transmitted to descendants, as was generally done before Weismann's work, for it is generally recognized that somatic characters whether inherited or acquired are not transmitted from generation to generation, the only thing which is transmitted being the germ-plasm. Weismann admitted in his later writings that the germ-plasm might be modified to a limited extent by certain environmental conditions, but he held that such

changes of the germ-plasm led to general and unpredictable changes in future generations which might be wholly different from those somatic changes in the parents which were directly produced by such environment. This view is now widely accepted.

Thus while Weismann's views on this subject underwent certain changes in the course of his long life, the opinions of his opponents have undergone so much greater and more important changes that it may be truly said that in the matter of the inheritance or non-inheritance of acquired characters the greater portion of the scientific world has come to Weismann's position.

Finally mention must be made of Weismann's theory of evolution which was a direct outgrowth of his theory of heredity. He maintained that evolution must depend upon an evolution of the germ-plasm and that this was brought about chiefly, if not entirely, by the mixture of different kinds of germ-plasms (amphimixis) in the union of the sex cells. There is no doubt that many variations are produced by amphimixis but in general these combinations of germ-plasms are not actual fusions; new combinations of inheritrance units are produced but not new units, and usually these new combinations split up in subsequent generations according to Mendelian rules, so that such temporary combinations of different germplasms do not usually lead to permanent modification, or to evolution, of the germ-plasm. On the other hand it is probable that Weismann underestimated the possible influence of environment in producing changes in the germ-plasm and hence its influence on evolution; at least it does not seem possible at present to explain the origin of many inherited mutations except by the influence of changed environment upon the developing germ cells.

In his belief in Natural Selection Weismann out-Darwined Darwin or any of the Darwinians. Darwin dealt only with the survival of individuals or races in the struggle for existence and was always inclined to assign a good deal of weight to the influence of environment in producing new races. Weismann would not admit the existence of any other factor of evolution than selection and he extended this principle from individuals or persons ("personal selection") to organs and tissues ("histonal selection") and

even to germinal units such as determinants and biophores ("germinal selection"). By means of an assumed struggle for nutriment between different determinants he believed that the weaker ones would tend to grow still weaker and to disappear while the stronger ones would increase in strength until they reached such importance that they were checked, or increased, by personal selection. And by a similar struggle between different biophores he showed that the *quality* of a determinant would be changed. By means of this highly ingenious but purely formal and hypothetical system he was able to explain the degeneration and disappearance of useless parts of an organism and the concordant modification of many different parts in the course of evolution.

Of all his theories those which grew out of his belief in the "Omnipotence of Selection" have found least confirmation in subsequent work. The Mutation Theory of deVries has come in to modify in certain important respects the theory of Darwin, and the work of Johannsen, Jennings, Pearl and others has shown that even "personal selection" has little or no influence in *creating* new types. And yet we have not seen the end of the selection doctrine. The elimination of the unfit is still the only natural means of accounting for fitness in organisms and we may well ponder these words of Weismann in the preface of his last book:

> "Although I may have erred in many single questions which the future will have to determine, in the foundation of my ideas I have certainly not erred. The selection principle controls in fact all categories of life units. It does not create the primary variations but it does determine the paths of development which these follow from beginning to end, and therewith all differentiations, all advances of organization and finally the general course of development of organisms on our earth, for everything in the living world rests on adaptation."

Clear thinking is necessary in the advance of science as well as fine technique and Weismann has demonstrated to a more or less scornful world the importance of brains as well as of hands and eyes in the discovery of truth. It does not fall to the lot of any man to make no mistakes, and in this respect Weismann was only human. But it has fallen to the lot of few men to do so much work of lasting value and to have so profound an influence on his

day and generation as was true of August Weismann. The spirit of his life and work may be summed up in the beautiful words with which he closes his essay on "Life and Death": "After all it is the quest after perfected truth, not its possession, that falls to our lot, that gladdens us, fills up the measure of our life, nay! hallows it."

EDWIN G. CONKLIN.

PRINCETON UNIVERSITY,
January, 1915.

MINUTES

MINUTES.

Stated Meeting January 1, 1915.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

The decease was announced of Charles Martin Hall, A.M., LL.D., of Niagara Falls, at Daytona, Florida, on December 27, 1914; æt. 51.

Prof. Edwin G. Conklin read an obituary notice of Prof. August Weismann.

Prof. William B. Scott read a paper on "The Isthmus of Panama in its Relation to the Animals of North and South America."

The Judges of the Annual Election of Officers and Councillors, held on this day between the hours of two and five in the afternoon, reported that the following named members were elected to be the Officers for the ensuring year, according to the Laws, Regulations and Ordinances of the Society.

President.

William W. Keen.

Vice-Presidents.

William B. Scott,
Albert A. Michelson,
Edward C. Pickering.

Secretaries.

I. Minis Hays,
Arthur W. Goodspeed,
Amos P. Brown,
Harry F. Keller.

Curators.

Charles L. Doolittle,
William P. Wilson,
Leslie W. Miller.

Treasurer.

Henry La Barre Jayne.

Councillors.

(To serve for three years.)
Henry H. Donaldson,
Theodore W. Richards,
Robert A. Harper,
Edwin G. Conklin.

Special Meeting January 14, 1915.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

Dr. J. C. Bose, of Calcutta, read a paper on "The Control of Nervous Impulse in Plant and Animal."

Stated Meeting February 5, 1915.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

An invitation was received from the University of North Carolina to be represented at the Inauguration of Edward Kidder Graham, as President, at Chapel Hill, on the twenty-first of April.

A letter was received from Prof. Allen C. Thomas presenting his resignation of membership.

The decease was announced of the following members:

Benjamin Sharp, M.D., at Moorehead, N. C., on January 23, 1915; æt. 57.

Cyrus Fogg Brackett, A.B., LL.D., at Princeton on January 29, 1915; æt. 82.

The following papers were read:

"The Surgery of the Civil War as Contrasted with the Surgery of the Present European War," by W. W. Keen, M.D.

"The Antediluvian Patriarchs on a Tablet from Nippur," by George A. Barton, Ph.D., which was discussed by Professor Learned and Mrs. Stevenson.

Stated Meeting March 5, 1915.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

Dr. David Jayne Hill, elected to membership in 1910, subscribed the Laws and was admitted into the Society.

Letters were received:

From the President appointing Prof. W. LeConte Stevens to represent the Society at the inauguration of Edward Kidder Graham, as President of the University of North Carolina.

From Prof. W. LeConte Stevens, accepting the appointment.

The decease of the following members was announced:

Arthur vonAuwers, at Berlin on January 24, 1915.

James Geikie, LL.D., D.C.L., at Edinburgh, on March 2, 1915; æt. 75.

The following papers were read:

"The Swedes, Governor Printz, and the Beginning of Pennsylvania," by Thomas Willing Balch.

"A Missing Chapter in International History," by Hon. David Jayne Hill, which was discussed by Mr. Carson, Prof. Learned, and Mr. Rosengarten.

Stated Meeting April 9, 1915.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

An invitation was received from the Trustees and Faculty of Allegheny College, to be represented at the celebration of the One Hundredth Anniversary of the founding of the College, to be held at Meadville, Pa., in the week beginning the twentieth of June, 1915.

The decease of the following members was announced:

Charles Francis Adams, LL.D., at Washington on March 20, 1915; æt. 80.

Frederick Winslow Taylor, M.E., at Philadelphia on March 21, 1915; æt. 59.

David K. Tuttle, Ph.D., at Philadelphia on April 7, 1915; æt. 79.

Prof. Charles C. Bass read a paper on "Some Important Factors which Influence Asexual Reproduction of Malaria Plasmodia in Man," which was discussed by Dr. Tyson, Dr. Henry Skinner, Dr. McFarland, and Dr. Keen.

Stated General Meeting April 22, 23, and 24, 1915.

Thursday, April 22, 1915.

ALBERT A. MICHELSON, Ph.D., Sc.D., LL.D., F.R.S.,
Vice-President, in the Chair.

Prof. Eliakim H. Moore, elected to membership in 1905, and Prof. Robert Andrews Millikan, elected to membership in 1914, having subscribed the Laws, were admitted into the Society.

The following papers were read:

"Devices for Facilitating the Analysis of Observations—More Particularly those of the Tides," by Ernest W. Brown, Sc.D., Professor of Mathematics, Yale University.

"On Linear Integral Equations in General Analysis," by Eliakim H. Moore, Ph.D., Sc.D., LL.D., Head of Department of Mathematics, University of Chicago.

"A Direct Solution of Fredholm's Equation with Analytic Kernel," by Preston A. Lambert, Professor of Mathematics, Lehigh University, Bethlehem, Pa.

"The Existence of a Sub-Electron?" by Robert A. Millikan, Ph.D., Professor of Physics, University of Chicago, which was discussed by Prof. Michelson.

"Local Disturbances in a Magnetic Field," by Francis E. Nipher, A.M., LL.D., Professor of Physics, Washington University, St. Louis.

"Explorations over the Surface of Telephonic Diaphragms Vibrating under Simple Impressed Sounds," by A. E. Kennelly, S.D., A.M., Professor of Electrical Engineering, Harvard University and H. O. Taylor, of Cambridge.

"The Hall and Corbino Effects," by Edwin Plimpton Adams, Professor of Physics, Princeton University. (Introduced by Prof. Magie.)

"Spontaneous Generation of Heat in Recently Hardened Steel," by Charles Francis Brush, Ph.D., Sc.D., LL.D., of Cleveland.

"Ruling and Performance of a Ten Inch Diffraction Grating," by A. A. Michelson, Ph.D., Sc.D., LL.D., Head of Department of Physics, University of Chicago.

Friday, April 23.

Morning Session—9.35 o'clock.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

The following papers were read:

"Heredity in Protozoa," by M. H. Jacobs, Ph.D., Assistant Professor of Zoölogy, University of Pennsylvania. (Introduced by Prof. McClung.)

"The Constitution of the Hereditary Material," by T. H. Morgan, Ph.D., Professor of Experimental Zoölogy, Columbia University, New York. (Introduced by Prof. E. G. Conklin.) Discussed by Prof. Conklin.

"The Problem of Adaptation as Illustrated by the Fur Seals of the Pribilof Islands" (illustrated by lantern slides), by George H. Parker, Sc.D., Professor of Zoölogy, Harvard University. Discussed by Professors Conklin and Cattell.

"An Interpretation of Sterility in Hybrids," by Edward M. East, Ph.D., Professor of Experimental Plant Morphology, Harvard University. (Introduced by Prof. Bradley Moore Davis.)

"Heterosis and the Effects of Inbreeding," by George H. Shull, Ph.D., Botanical Investigator, Station for Experimental Evolution, Carnegie Institution. (Introduced by Prof. Bradley M. Davis.)

"The Significance of Sterility in Œnothera," by Bradley M. Davis, Ph.D., Professor of Botany, University of Pennsylvania.

The preceding three papers were discussed by Prof. Parker.

"Morphology and Development of Agaricus rodmani," by George F. Atkinson, Ph.D., Head of Department of Botany, Cornell University.

"The Large-fruited American Oaks," by William Trelease, Sc.D., LL.D., Professor of Botany, University of Illinois, Urbana.

"Relationships of the White Oaks of Eastern North America," by M. V. Cobb. (Introduced by Prof. Trelease.)

"The Present Need in Systematic Botany," by L. H. Bailey, LL.D., late Director of the College of Agriculture, Cornell University.

Afternoon Session—2 o'clock.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

The following papers were read:

"A Convenient Form of Receiver for Fractional Distillations under Diminished Pressure,'" by Marston T. Bogert, LL.D., Professor of Chemistry, Columbia University, New York.

"The Cymene Carboxylic Acids," by J. R. Tuttle and Marston T. Bogert, of Columbia University, New York.

"Syringic Acid and its Derivatives," by E. Plaut and Marston T. Bogert, of Columbia University, New York.

The three preceding papers were discussed by Profs. Keller and Scott.

"The Relation of Ductless Glands to Dentition and Ossification," by William J. Gies, Ph.D., Professor of Biological Chemistry, Columbia University. (Introduced by Prof. Harry F. Keller.)

"Gastro-Intestinal Studies," by Philip B. Hawk, Ph.D., Professor of Physiological Chemistry and Toxicology, Jefferson Medical College, Philadelphia. (Introduced by Dr. W. W. Keen.) Discussed by Prof. Scott.

"On the Rate of Evaporation of Ether from Oils and its Application in Oil-Ether Colonic Anæsthesia," by Charles Baskerville, Ph.D., Professor of Chemistry, College of the

City of New York. (Introduced by Prof. J. P. Remington.) Discussed by Profs. Scott and Remington.

"On Oral Endamebiosis," by Allen J. Smith, M.D., Sc.D., LL.D., Professor of Pathology, University of Pennsylvania. Discussed by Prof. Bogert.

"Certain Factors Conditioning Nervous Responses," by Stewart Paton, M.D., Lecturer in Biology, Princeton University. Discussed by Profs. Donaldson and Scott.

"The Rights and Obligations as to Neutralized Territory," by Charlemagne Tower, LL.D., of Philadelphia.

"Physiographic Features as a Factor in the European War," by Douglas W. Johnson, Ph.D., Associate Professor of Physiography, Columbia University. (Introduced by Mr. Henry G. Bryant.)

"The Pronouns and Verbs in Sumerian," by J. Dyneley Prince, Ph.D., Professor of Semitic Languages, Columbia University, New York. (Read by title.)

"A New Form of Nephelometer," by J. T. W. Marshall, Harriman Research Laboratory, Roosevelt Hospital, New York.

Dr. Stewart Paton a newly-elected member and the Hon. Simeon E. Baldwin, elected to membership in 1910, subscribed the Laws and were admitted into the Society.

Friday Evening—8.15 o'clock.

William Morris Davis, Sc.D., Ph.D., Professor Emeritus of Geology, Harvard University, gave an illustrated lecture, "On New Evidence for Darwin's Theory of Coral Reefs." A statement of the chief results of a Shaler Memorial Voyage across the Pacific in 1914, with Studies of the Fiji Group, New Caledonia, the Loyalty Islands, the New Hebrides, the Great Barrier Reef of Australia and the Society Islands.

Saturday, April 24.

Executive Session—9.30 A. M.

William W. Keen, M.D., LL.D., President, in the Chair.

Pending nominations for membership were read and spoken to.

Dr. L. A. Bauer and Secretary Brown were appointed tellers of election and the Society proceeded to ballot for members.

The tellers reported that the following nominees had been elected to membership:

Residents of the United States.

John J. Abel, M.D., Baltimore, Md.
Edwin Plimpton Adams, Ph.D., Princeton, N. J.
Walter Sydney Adams, Pasadena, Cal.
John Merle Coulter, Ph.D., Chicago, Ill.
Whitman Cross, Ph.D., Washington, D. C.
William J. Gies, M.D., New York City.
Philip Bovier Hawk, Ph.D., Philadelphia.
John Fillmore Hayford, Evanston, Ill.
Emory Richard Johnson, Sc.D., Philadelphia.
John Anthony Miller, Ph.D., Swarthmore, Pa.
Thomas Hunt Morgan, Ph.D., New York.
William Fogg Osgood, Ph.D., Cambridge, Mass.
Raymond Pearl, Ph.D., Orono, Me.
Theobald Smith, M.D., Boston, Mass.
John Zeleny, Ph.D., Minneapolis, Minn.

Morning Session—10 o'clock.

WILLIAM B. SCOTT, Sc.D., LL.D., Vice-President, in the Chair.

The following papers were read:

"Opium in the Bible," by Paul Haupt, Ph.D., Professor of Semitic Languages, Johns Hopkins University, Baltimore.

"Divisions of the Pleistocene of Europe and the Periods of the Entrance of Human Races," by Henry Fairfield Osborn, Sc.D., LL.D., Research Professor of Zoölogy, Columbia University, N. Y.

"The Occurrence of Algæ in Carbonaceous Deposits," by Charles A. Davis, Ph.D., of U. S. Bureau of Mines. (Introduced by Prof. Marston T. Bogert.) Discussed by Profs. Scott and B. M. Davis.

"Additions to the Fauna of the Lower Pliocene Snake Creek Beds, Nebraska," by W. J. Sinclair, Ph.D., Curator of Vertebrate Paleontology, Princeton University. (Introduced by Prof. W. B. Scott.) Discussed by Prof. Scott.

"Tertiary Vertebrate Faunas of the North Coalinga Region of California," by John C. Merriam, Ph.D., Professor of Paleontology and Historical Geology, University of California.

"The Rôle of the Glacial Anticyclone in the Air Circulation of the Globe," by William H. Hobbs, Ph.D., Professor of Geology, University of Michigan.

"Note on the Sun's Temperature," by Henry Norris Russell, Ph.D., Professor of Astronomy, Princeton University.

"Radial Velocities in the Orion Nebula," by Edwin B. Frost, D.Sc., Director of Yerkes Observatory, Williams Bay, Wis. Discussed by Prof. Russell.

"Some Results from the Observation of Eclipsing Variables," by Raymond S. Dugan, Assistant Professor of Astronomy, Princeton University. (Introduced by Prof. H. N. Russell.)

"The Variable Stars TV, TW, and TX Cassiopeiæ," by R. J. McDiarmid, Fellow, Princeton University. (Introduced by Prof. H. N. Russell.)

"The Euler-Laplace Theorem on the Rounding Up of the Orbits of the Heavenly Bodies under the Secular Action of a Resisting Medium," by T. J. J. See, Ph.D., U. S. Naval Observatory, Mare Island, Cal.

"The Work in Atmospheric Electricity aboard the 'Carnegie,'" by L. A. Bauer, Ph.D., D.Sc., Director of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, and W. F. G. Swann, D.Sc.

"Tammuz and Osiris," by George A. Barton, Ph.D., Prof. of Biblical Literature and Semitic Languages, Bryn Mawr College, which was discussed by Dr. Jastrow.

Afternoon Session— 2 o'clock.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

Dr. John Fillmore Hayford, a newly elected member, subscribed the Laws and was admitted into the Society.

A portrait of Dr. Edgar F. Smith, of Philadelphia, was presented to the Society by Dr. J. H. Penniman on behalf of the donor.

The following papers were read:

"One Dimensional Gases and the Reflection of Molecules from Solid Walls."

"Recent Progress in the Study of the Iodine Resonance Spectra, with a description of a Long Focus Spectroscope of High Power," by Robert Williams Wood, A.B., LL.D., Professor of Experimental Physics, Johns Hopkins University. Discussed by Dr. Brush, Prof. Noyes and Dr. Webster.

Symposium on the Earth: Its Figure, Dimensions and the Constitution of Its Interior

"From the Astronomical Standpoint," by Frank Schlesinger, Ph.D., Director of Allegheny Observatory, Pittsburgh.

"From the Geological Standpoint," by T. C. Chamberlin, Ph.D., LL.D., Head of Department of Geology, University of Chicago.

"From the Seismological Standpoint," by Harry Fielding Reid, Ph.D., Professor of Dynamical Geology and Geography, Johns Hopkins University, Baltimore.

"From the Geophysical Standpoint," by John F. Hayford, Director of College of Engineering, Northwestern University, Evanston, Ill. (Introduced by Prof. Schlesinger.)

These papers were discussed by Professors H. F. Reid, Arthur G. Webster, E. W. Brown, C. L. Doolittle, Frank Schlesinger and W. H. Hobbs.

Stated Meeting May 7, 1915.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

Letters accepting membership were received from:

John J. Abel, M.D., Baltimore, Md.
Edwin Plimpton Adams, Ph.D., Princeton, N. J.
John Merle Coulter, Ph.D., Chicago, Ill.
Whitman Cross, Ph.D., Washington, D. C.
William J. Gies, M.D., New York City.
Philip Bovier Hawk, Ph.D., Philadelphia.
Emory Richard Johnson, Sc.D., Philadelphia.
John Anthony Miller, Ph.D., Swarthmore, Pa.

Thomas Hunt Morgan, Ph.D., New York.
Raymond Pearl, Ph.D., Orono, Me.
Theobald Smith, M.D., Boston, Mass.

An invitation was received from the Johns Hopkins University to be represented at the Inauguration of Frank Johnson Goodnow, as President, on May 20, 1915.

The following papers were read:

"Oil Concentration of Ores," by Howard W. DuBois, M.E. (Introduced by Dr. Harry F. Keller.) Discussed by Mr. Lehman.

"Concretions in Streams Formed by the Agency of the Blue-Green Algæ and Related Plants," by H. Justin Roddy, M.S. (Introduced by the Secertaries.) Discussed by Dr. Harshberger, Mr. Sanders, and Prof. Keller.

"The Conditions of Black Shale Deposition as illustrated by the Kupferschiefer and Lias of Germany," by Charles Schuchert.

Stated Meeting October 1, 1915.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

Professors Philip B. Hawk, Emory R. Johnson, and John Anthony Miller, newly-elected members, subscribed the Laws and were admitted into the Society.

Letters accepting election to membership were received from

Prof. Walter S. Adams.
Prof. John F. Hayford.
Prof. William F. Osgood.
Prof. John Zeleny.

Invitations were received:

From the Secretary of State to participate in the Second Pan-American Scientific Congress to be held under the auspices of the Government of the United States, at the city of Washington from December 27, 1915, to January 8, 1916.

From the Trustees and Faculty of Vassar College, to be represented at the celebration of the Fiftieth Anniversary of the opening of Vassar College during the week beginning October 10, 1915.

The decease of the following members was announced:

Mr. Samuel Dickson, at Philadelphia, on May 28, 1915, æt. 78.

Hon. James T. Mitchell, at Philadelphia, on July 4, 1915, æt. 81.

Mr. Frederick Prime, at Atlantic City, on July 14, 1915, æt. 69.

Sir James A. H. Murray, at Oxford, England, on July 26, 1915, æt. 78.

Prof. Frederick W. Putnam, at Cambridge, Mass., on August 14, 1915, æt. 76.

Mr. John T. Morris, at Bretton Woods, N. H., on August 15, 1915, æt. 67.

Dr. Austin Flint, at New York, on September 22, 1915, æt. 79.

The following papers were read:

"Timber Studies in the Mississippi Bottom Lands," by Henry C. Cowles, Ph.D., of Chicago, which was discussed by Professors Harshberger and Kraemer.

"A Practical Rational Alphabet," by Benjamin Smith Lyman, A.B.

Stated Meeting November 5, 1915.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

Prof. Ulric Dahlgren read a paper on "The Production of Heat by Animals."

Stated Meeting December 3, 1915.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

An invitation was received from the American Association for the Advancement of Science to send one or more delegates to its meeting to be held at Columbus, Ohio, December 27, 1915, to January 1, 1916.

Mr. H. H. Harjes, in accordance with the expressed direction of his father, the late John H. Harjes, of Paris, transmitted to the Society Dr. Franklin's bamboo cane with a horn handle, in the upper hollow chamber of which he was accustomed to carry oil and from it in his walks he dropped oil upon the water to watch its effect upon wind-beaten pools.

The decease was announced of William Brooke Rawle, A.B., at Philadelphia, on November 30, 1915, æt. 72.

The following papers were read:

"Some of the Neuro-retinal Interpretations of Increased Vascular and Increased Intracranial Pressure, being a Clinical Communication," by Dr. George E. deSchweinitz.

"The Geology of Parahyba and Rio Grande do Norte, Brazil," by Ralph H. Soper, communicated by Prof. John C. Branner.

"The Geology of Ceará and Piauhy, Brazil," by H. L. Small, communicated by Prof. John C. Branner.

Dr. W. W. Keen presented the Annual Address of the President.

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